Frontiers in Artificial Intelligence and Applications

LEADING THE WEB IN CONCURRENT ENGINEERING

Next Generation Concurrent Engineering

Edited by
Parisa Ghodous
Rose Dieng-Kuntz
Geilson Loureiro

IOS Press

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LEADING THE WEB IN CONCURRENT ENGINEERING

Frontiers in Artificial Intelligence and Applications

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Vol. 132. K. Nakamatsu and J.M. Abe (Eds.), Advances in Logic Based Intelligent Systems – Selected Papers of LAPTEC 2005
Vol. 131. B. López et al. (Eds.), Artificial Intelligence Research and Development

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Edited by

Parisa Ghodous

University Lyon I, France

Rose Dieng-Kuntz

INRIA, Sophia Antipolis, France

and

Geilson Loureiro

LIT, INPE, Brazil

IOS Press

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USA
fax: +1 703 323 3668
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Preface

It is our great pleasure to welcome you to the 13th ISPE International Conference on Concurrent Engineering: Research and Applications, CE2006 being held in Antibes, France. The previous events were held in Dallas, Texas, USA (2005), Beijing, China (CE2004), Madeira Island, Portugal (CE2003), Cranfield, UK (CE2002), Anaheim, USA (CE2001), Lyon, France (CE2000), Bath, UK (CE99), Tokyo, Japan (CE98), Rochester, USA (CE97), Toronto, Canada (CE96), McLean, USA (CE95), Pittsburgh, USA (CE94). CE2007 and CE2008 are planned for Brazil and Australia, respectively.

The CEXX conference series were launched by the International Society for Productivity Enhancement (ISPE) which, for more than a decade now, has constituted an important forum for international scientific exchange on concurrent engineering. These conferences attract more than a hundred researchers, industrials and students interested in the recent advances in concurrent engineering research and applications. Concurrent engineering is known as a strategic weapon to achieve industrial competitiveness by developing products better, cheaper and faster using multi-functional teamwork.

The underlying focus of CE2006 Conference is in developing new methodologies, techniques and tools based on Web technologies required to support the key objectives of CE. For several years, with different technologies of information diffusion and sharing provided by the Web, new opportunities have appeared to improve the concurrent engineering approach. Bringing together concurrent engineering with Web technology and applications constitutes the strong and innovative points of the CE2006 Conference. The Web is not merely an immense book where people can search, browse, and view information. It is also a vast database that can allow computers to do more useful work. By developing a Web that holds information for both human and machine processing, people solve problems that would otherwise be too tedious or complex to solve (www.w3.org).

The International Program Committee has decided to select the following major areas for CE2006:

Keynote and invited papers
Web services
Interoperability and interfacing
Collaborative, mobile and multimodal environment
Semantic Enterprise, Semantic Web and ontologies
Knowledge in CE
Global Standardization
Information Systems in CE
Semantic indexing of documents
Innovation and business strategies
Design, manufacturing and services
Cost engineering
Education, social aspects and humanities
Tools and applications

We would like to thank all the authors for the high quality of their papers. We would like also to acknowledge the contribution of the key invited speakers, CE2006 International Program Committee and all session chairs in making a successful conference. We thank sincerely the members of the executive and organizing committees who helped in all aspects of organizing the conference (in particular Moisés Dutra Lima, Lionel Médini and Monique Simonetti). Last, we would like to gratefully acknowledge the institutional support and encouragement that we have received from our sponsors (in particular ISPE, INRIA, UCBL, W3C) and the funding received from Conseil Régional PACA, Ministère francais des affaires étrangères.

Parisa Ghodous
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France

Geilson Loureiro
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LIT, INPE
Brazil

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Chimay J. Anumba	Loughborough University, UK, c.j.anumba@lboro.ac.uk
Ernesto Araujo	LIT-INPE, Brazil, ernesto@lit.inpe.br
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Álvaro Azevedo Cardoso	University of Taubaté, São Paulo, Brazil, azevedo@unitau.br
Antônio Batocchio	UNICAMP, São Paulo, Brazil, batocchi@fem.unicamp.br
Alain Bernard	Institut de Recherche en Communications et en Cybernétique de Nantes, France, Alain.Bernard@irccyn.ec-nantes.fr
Milton Borsato	CEFET-PR, Paraná, Brazil, mborsato@cefetpr.br
Omar Boussaid	University of Lyon 2, France, Omar.Boussaid@univ-lyon2.fr
Lionel Brunie	INSA de Lyon, France, Lionel.Brunie@insa-lyon.fr
Sylvie Calabretto	LIRIS Laboratory University of Lyon 1, France, sylvie.calabretto@insa-lyon.fr
Osíris Canciglieri Junior	PUCPR, Paraná, Brazil, osiris.canciglieri@pucpr.br
Jianzhong Cha	Beijing Jiaotong University (BJTU), China, jzcha@center.njtu.edu.cn
Hong Chao Zhang	Texas University, USA, hong-chao.zhang@ttu.edu
Jean-Marc Chatelard	Schneider Electric, France FR-ISO-Chatelard@mail.schneider.fr
Russell W. Claus	NASA Glen, USA, russell.w.claus@nasa.gov
Olivier Corby	INRIA, Sophia Antipolis, France, Olivier.Corby@sophia.inria.fr
Oscar Corcho	University of Manchester, UK, Oscar.Corcho@manchester.ac.uk
Carlos Alberto Costa	UCS, Brazil, cacosta@ucs.br
Ricky Curran	Queens University Belfast, UK, r.curran@qub.ac.uk
Anne-Francoise Cutting-Decelle	University of Evry, France, afcd@skynet.be
Marcelo da Silva Hounsell	UDESC, Santa Catarina, Brazil, marcelo@joinville.udesc.br

Edgard Dias Batista Jr.	UNESP, Brazil, edgard@feg.unesp.br
Martin Dzbor	Open University, UK, m.dzbor@open.ac.uk
Liping Fang	Ryerson University, Canada, lfang@ryerson.ca
Fatima Farinha	EST-Universidade do Algarve, Portugal, mfarinha@ualg.pt
Shuichi Fukuda	Tokyo Metropolitan Institute of Technology, Japan, shufukuda@aol.com
Fabien Gandon	INRIA, Sophia Antipolis, France, Fabien.Gandon@sophia.inria.fr
Sanjay Goel	University at Albany, USA, sgoel@uamail.albany.edu
Asun Gomez Perez	Universidad Politecnica de Madrid, Spain, asun@fi.upm.es
Luiz Gonzaga Trabasso	ITA, São Paulo, Brazil, gonzaga@ita.br
Lilia Gzara Yesilbas	University of Nancy 1, France, Lilia.Gzara@cran.uhp-nancy.fr
Mohand-Said Hacid	University of Lyon 1, France, mshacid@bat710.univ-lyon1.fr
Martin Hardwick	RPI, STEP Tools, Inc, USA, hardwick@steptools.com
Kazuo Hatakeyama	Universidade Tecnológica do Paraná, Paraná, Brazil, hatakeyama@pg.cefetpr.br
Pavel Ikonomov	Western Michigan University, USA, pavel.ikonomov@wmich.edu
Roger Jiao Jianxin	Nanyang Technological University, Singapore, jiao@pmail.ntu.edu.sg
Robert Judd	Ohio University, USA, judd@ohio.edu
Farzad Khosrowshahi	Salford University, UK, F.Khosrowshahi@salford.ac.uk
Alain Leger	France Telecom, France, alain.leger@francetelecom.com
Lang Lihui	Beihang University, China, lang@buaa.edu.cn
Celson Lima	UNINOVA, Portugal, clima@uninova.pt
Ashley Lloyd	Curtin Business School, Australia, Ashley.Lloyd@cbs.curtin.edu.au
Francisco Antonio Lotufo	UNESP, Brazil, falotufo@feg.unesp.br
Yiping Lu	Beijing Jiaotong University (BJTU), China, yplu@center.njtu.edu.cn
Roland Maranzana	University of Quebec, Canada, roland.maranzana@etsmtl.ca
Henrique Martins	UNESP, Brazil, hmartins@eng.aedb.br
Nada Matta	Université Technologie de Troyes, France, Nada.Matta@utt.fr
Lionel Médini	LIRIS Laboratory University of Lyon 1, France, lionel.medini@liris.univ-lyon1.fr
Enrico Motta	The Open University, UK, e.motta@open.ac.uk
Jorge Muniz	FEG, UNESP, São Paulo, Brazil, jorgemuniz@feg.unesp.br
Suren N. Dwivedi	University of Louisiana at Lafayette, USA, snd7483@louisiana.edu
Carmen Neyra Belderrain	ITA, São Paulo, Brazil, carmen@mec.ita.br

Jefferson de Oliveira Gomes	ITA, Brazil, gomes@ita.br
Jos P. van Leeuwen	Eindhoven University of Technology, The Netherlands, j.p.v.leeuwen@bwk.tue.nl
Francis Pahng	Zionex, Inc., South Korea, francis_pahng@zionex.com
Marc Pallot	EsoCE-NET, France, marc.pallot@esoce.net
Kulwant S Pawar	Nottingham University, UK, kul.pawar@nottingham.ac.uk
Marcus Vinicius Pessoa	Brazilian Air Force, São Paulo, Brazil, mvppessoa@gmail.com
Guy Pierra	LISI/ENSMA, France, pierra@ensma.fr
Maciej Pietrzyk	Akademia Gorniczo-Hutnicza, Poland, pietrzyk@metal.agh.edu.pl
Jerzy Pokojski	SIMR, Poland, jerzy.pokojski@simr.pw.edu.pl
Mike Pratt	LMR Systems, UK, mike@lmr.clara.co.uk
Roy Rajkumar	Cranfield University, UK, r.roy@cranfield.ac.uk
Zbigniew W. Ras	University of North Caroline of Charlotte, USA, ras@uncc.edu
Olivier Rérolle	CETIM, Center for Technology and Innovation Management, Olivier.Rerolle@CeTIM.org
Hamid Reza Arabnia	University of Georgia, USA, hra@cs.uga.edu
Ubirajara Rocha Ferreira	UNESP, Brazil, ferreiur@feg.unesp.br
Roberto Rosso	UDESC, Santa Catarina, Brazil, dcc2rsurj@joinville.udesc.br
Marta Sabou	The Open University, UK, R.M.Sabou@open.ac.uk
Valerio Salomon	UNESP, Brazil, salomon@feg.unesp.br
Behzad Shariat	LIRIS laboratory, University of Lyon 1, France, bshariat@bat710.univ-lyon1.fr
Ong Soh Kim	National University of Singapore, Singapore, mpeongsk@nus.edu.sg
Katia Sycara	Carnegie Mellon University, USA, katia@cs.cmu.edu
Derrick Tate	Texas Tech University, USA, d.tate@ttu.edu
Philippe Thiran	University of Namur, Belgium, pthiran@fundp.ac.be
Klaus-Dieter Thoben	University of Bremen and BIBA, Germany, tho@biba.uni-bremen.de
Farouk Toumani	LIMOS-ISIMA, Aubière, France, ftoumani@isima.fr
Amy Trappey	Tsing Hua University, Taiwan, trappey@ie.nthu.edu.tw
Jenny Ure	Edinburgh, UK, jure2@inf.ed.ac.uk
Maria Teresa Villalobos	CENPRA, São Paulo, Brazil, maria-teresa.villalobos@cenpra.gov.br
Matthew Wall	MIT, USA, ce2006@lancet.mit.edu
Nel Wognum	University of Twente, the Netherlands, p.m.wognum@bbt.utwente.nl
Robert Young	Loughborough University, UK, r.i.young@lboro.ac.uk

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LIRIS: Laboratoire d'InfoRmatique
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CNRS: Centre National de la
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Contents

Workshop 2: Interoperability in CE

Collaborative, Mobile and Multimodal Working Environment

Semantic Enterprise, Semantic Web and Ontologies in CE

Knowledge in CE

Global Standardization and CE

Information Systems in CE

Semantic Indexing of Documents

Innovation and Business Strategies

Design, Manufacturing and Services in CE

Cost Engineering in CE

Keynotes and Invited Papers

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P. Ghodous et al. (Eds.)
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The Ubiquitous Web

Dave Raggett
Volantis Systems, UK & W3C
e-mail: dsr@w3.org

Abstract. Networked devices are increasingly pervasive, ranging from RFID tags to supercomputers. How can Web technologies simplify the development of distributed Web applications that dynamically adapt to the context, including user preferences, device capabilities and environmental conditions? This talk will introduce the Ubiquitous Web, and its dependence on device coordination, layered application models, and the role of Semantic Web technologies to support resource descriptions, resource discovery, and modeling of trust and identity relationships.

Short biography. Dr. Raggett is employed by Volantis Systems and works on assignment to the W3C as a W3C Fellow. He has been closely involved with the development of Web standards since 1992, contributing to work on HTML, HTTP, XForms and more recently to work on voice and multimodal Web applications. His current focus is on driving the Ubiquitous Web, a vision for how to combine the Web and pervasive computing, as part of W3C's mission to fulfill the potential of the Web.

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Concurrent Engineering – past, present and future

P.M. Wognum, R. Curran, P. Ghodous, R. Goncalves, A. Lloyd, R. Roy
Members ISPE board, International Society of Productivity Enhancement/ISPE

Abstract Concurrent Engineering received much attention all over the world in the past two decades. The concept comprises integration of technology, but also of various functional areas within and between organisations with a strong focus on enterprise-wide processes. In addition, new forms of business have emerged, due to new technological developments. In the literature, much emphasis has been given to such new technological development, but the importance of applied research is increasingly being recognized. The concept of Concurrent Engineering has strongly developed over the years and has been given many different names. In the ISPE lecture to be presented at the conference, the development of the concept will be addressed, as demonstrated through the work published in the many proceedings of the CE conference. Various areas for current and future research and application will be presented, and reference made to the future relevance of concurrent engineering as a discipline.

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P. Ghodous et al. (Eds.)
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Product Life Cycle Management: a solution to manage innovation for manufacturing Companies

Francis BERNARD
EADS, France

Abstract. The presentation describes the challenges that each enterprise is facing today, in the global market place, and what are the in initiatives that should be taken to address these challenges. .PLM is then described as a combination of enterprise organization transformations, new business processes and IT solutions which allow addressing such initiatives. An overview of the main innovative PLM software technology is then shown. The presentation ends with a short update on Dassault Systemes and its commitment to the academic community.

Keywords. Product Life Cycle Management (PLM)

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P. Ghodous et al. (Eds.)
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Towards Systems Integration Technology

Tetsuo TOMIYAMA
Faculty of Mechanical, Maritime and Materials Engineering
Delft University of Technology, The Netherlands

Abstract. In modern concurrent engineering practices, product development of complex multi-disciplinary products is performed by a team composed of experts from various disciplines such as mechanical design, electronics design, production engineering, industrial design, marketing, finance, sales, services, procurement, etc. Within this formation of team, it is usually the leader who makes decisions and performs systems integration. While in team working, the leader's role is often wrongly mixed with the role of manager. The net result is often the team leader performs the roles of decision maker, manager, and systems integrator. Due to these practices, there is even a belief that the "art" of systems integration can only be learned through experiencing many positions, accumulating experiences and skills. Accordingly, systems integration cannot be discussed and taught in schools. This paper tries to attack this myth and to establish systems integration technology as a discipline that can be studied, discussed, and taught.

Keywords. Systems integration, product architecture, multi-disciplinary product development, conceptual design

1. Systems Integration in Multi-Disciplinary Product Development

Developing complex products such as contemporary mechatronics products is by definition a multidisciplinary activity performed by a team composed of experts from various domains such marketing and sales, finance, mechanical design, electronics design, software development, procurement, production, maintenance, and environment. After customer requirements are identified and the company's strategy for those products are determined, the product architecture is defined. This defines also division of the entire project into mono-disciplinary domains on which domain experts can concentrate their effort. Since in many industries, concurrent engineering is a standard practice, these domain experts concurrently work in a team environment.

The concurrent engineering discipline encourages designers to have close contacts with each other during the development process. Therefore, not only at the end of the individual activities, but also during these activities, design results are communicated and integrated. At the end of the process, the final design information is transferred to the production phase.

To design an innovative, excellent, competitive product, in addition to these mono-disciplinary activities, systems integration technology must be excellent. Systems integration is not just summing up elements of design. At the very beginning of the product development process, the product architecture is determined. The architecture not only refers to components of the system and their interactions, but also dictates how the entire product functions based on which technology. For example, the decision that

a machine uses optical sensors (as opposed to mechanical sensors) influences not only mechanical design but also electronics design and software development.

2. Systems Integration Technology

Systems integration addresses three important aspects particularly in multi-disciplinary product development processes. The first is to design product architecture which determines the systems boundary for individual mono-disciplinary design and engineering processes, and the overall organization of components (not necessarily only physical layouts, but functional structure, control structure, buy-or-make decisions, etc.). The decisions made at this stage not only determine the product architecture but also greatly influence later product life cycle stages (such as production, maintenance, and recycling). Eventually, these may influence even the organization of the development team and resources.

The second is coordination of such mono-disciplinary design and engineering processes. The coordination means during the development process, information has to be communicated among different domain experts but sometimes this can include conflicts and contradictions. These conflicts and contradictions are usually solved by negotiations or by the authority of the project leader (chief engineer) often involving compromises of interests of different experts.

The third element of systems integration is the integration of individual mono-disciplinary design and engineering processes towards the end of the product development. This includes building elementary design results into a whole product, decisions over later life cycle stages (such as production, maintenance, etc.). During this process, again conflicts and contradictions can be found which is the focus of the second aspect.

In summary, systems integration technology is not just a discipline or decision making process but a combination of variety of activities that have the greatest impact on the whole product development and product life cycle. It is not just technical but also managerial decision making. It involves communication, negations, and compromises among domain experts and requires all knowledge about the product and its life cycle.

3. Systems Integrator

Due to the nature of systems integration activities, it is recognized that a systems integrator has to be an excellent engineer who has long experiences and extensive knowledge in every single aspect of the product and its life cycle (such as mechanical design, production, and control design). The systems integrator has to make crucial decisions about systems architecture.

Therefore, he/she often is a project leader who makes final decisions at various points in product development. This requires authority and responsibility to control processes, resources (financial, human, technology, knowledge, etc.), which entitles him a function of manager.

Consequently, in many places in industry, a systems integrator plays multiple roles of pure systems integrator, project leader, and even manager. It is often believed that the person needs long experiences with substantial knowledge and understanding in

every aspect of the product and its life cycle. In other words, because systems integration is not a technology but a collection of experiences, it is believed difficult or even impossible to teach systems integration as a technology and to train systems integrators in a systematic way.

However, a project leader is not or does not have to be a systems integrator. A project leader is a person who makes final decisions during the product development process. He/she does not have to prepare options from which the final solution is selected. A manager is a person who manages the process and necessary resources. He/she does not have to be a project leader nor a systems integrator.

The core concept of this paper is to try to establish systems integration as a systematized technology. By properly identifying the function of systems integrator, the project leader is able to make decisions over crucial aspects in product architecture and development processes more rationally, and to coordinate the process more efficiently. The manager's role should not be mixed with the systems integrator's role or with the project leader's.

The systems integrator has three roles to play during the product development process as identified in the previous section:

- To design product architecture which determines the systems boundary and the overall organization of components.
- To coordinate mono-disciplinary design and engineering processes by communicating information among and solving conflicts and contradictions.
- To integrate individual mono-disciplinary design and engineering processes towards the end of the product development.

4. Toward Systems Integration Technology

Since systems integration is not established as a technology, we need to make research in doing so. We can outline here a possible approach as follows.

First, the analysis on existing practices is necessary. However, we need to distinguish complex product development due to multi-disciplinarity and difficult product development due to size (mega projects) and technological difficulties in a mono-discipline. While these two are typical examples that require good systems integration technology, they may have different emphases. For example, systems integrators for mechatronics products or aircrafts can behave differently from those of ultra-tall skyscrapers.

Second, best practices must be identified to form a basis for a theory of systems integration. This should cover the three aspects of systems integration, i.e., designing systems architecture, coordinating mono-disciplinary design and engineering processes, and integrating results of individual processes.

Establishing a theory of systems integration will be the core in this research. This will not be necessarily a theory per se, though, and can include practically usable documents such as manuals, cookbooks, etc. According to the identified three key roles of systems integrator, at least three subtheories must be established, namely:

- Design methodologies of product architecture including the systems boundary and the overall organization of components.

- Methodologies to coordinate mono-disciplinary processes, in particular, a method to identify conflicts and contradictions as early as possible and to solve them.
- Methodologies to integrate results of individual mono-disciplinary design and engineering processes.

5. Conclusions

This research is a first step towards establishing systems integration technology that lends itself to more efficient concurrent engineering practices for complex multi-disciplinary products. Typically, disciplines can include mechanical design, electronics design, control engineering, software engineering, production engineering, industrial design, marketing, supply chain management, finance, sales, maintenance, and services.

The establishment of systems integration technology will clarify the differences between systems integrator, project leader, and project manager. Possible separation of these functions based on a scientific discipline of systems integration technology will facilitate more efficient product development, more rational decision making processes, and consequently better product quality.

Systems integration is no an “art”. It is often believed that systems integration can only be learned by experiencing many positions and by accumulating experiences and skills. On the contrary, systems integration should be discussed and taught scientifically in schools.

This paper identified three possible areas of future research; design methodologies of product architecture including the systems boundary and the overall organization of components; methodologies to coordinate mono-disciplinary processes, in particular, a method to identify conflicts and contradictions as early as possible and to solve them; and methodologies to integrate results of individual mono-disciplinary design and engineering processes.

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Collaborative Product Development: EADS Pilot Based on ATHENA Results

Nicolas Figay
European Aeronautic Defence and Space Company N.V., Corporate Research Center, EADS – CCR, France, email: nicolas.figay@eads.net

ATHENA research program proposes innovative approach to address needs for interoperability of enterprise applications. It addresses in particular the area of Collaborative Product Design, for Aerospace but also other manufacturing sectors. Innovation comes from a holistic approach of the problem at enterprise, knowledge, ICT and semantic levels. It implies simultaneous advanced usage of technologies coming from various domains like enterprise modeling, Model Driven software engineering, Service Oriented Architecture, Collaborative Executable Business Process engineering and Semantic reconciliation. In the Aerospace sector, but also for numerous other industrial sectors (as automotive, furniture, ships, building…), current trend is to develop Product Life Cycle Management approaches across the virtual enterprise, with earlier consideration of downstream phases when designing product system, and important role of "Product Data Management", "Product Data Exchange and Sharing" and "Change and Configuration Management processes". This paper describes the used way to define accurate Aerospace Collaborative Product Development pilots, in order to reach ATHENA objectives in term of scientific achievement and business impact, and with as a result definition of a first set of pilots and a proposal for Networked Enterprise Collaborative Product Definition infrastructure.

INTRODUCTION

In manufacturing area, increased collaboration among enterprises during the entire product life cycle is a global trend; organizations are transforming themselves into "networked organizations" dedicated to Collaborative Product Development. To achieve this, enterprise systems and applications need to be interoperable in order to achieve seamless business interaction and product data sharing and exchange (SAVE, 1999) across organizational, discipline and computational boundaries (IDEAS, 2003).

Currently, enterprises face many difficulties related to lack of interoperability. Interoperability, defined as "the ability of two or more systems or components to exchange information and to use the information that has been exchanged", needs to be addressed in respect of all layers of an enterprise (including ICT Systems, Knowledge, Business and Semantics). It needs to be tackled using a holistic perspective, a multi-disciplinary approach, and by bringing together the best research teams, industry expertise and ICT suppliers (IDEAS, 2003).

ATHENA aims to be the most comprehensive and systematic European research initiative in IT to remove barriers to interoperability, to transfer and apply the research results in industrial sectors, and to foster a new networked business culture. Building on its vision statement, "by 2010, enterprises will be able to seamlessly interoperate with others", ATHENA aims to enable interoperability by providing a comprehensive Interoperability Framework.

In ATHENA, Research and Development is executed in synergy and collaboration with Community Building: research is guided by business requirements defined by a broad range of industrial sectors and integrated into Piloting and Training.

EADS Research Centre is the representative of the Aerospace and Defense sector in ATHENA research program, and by extension of the manufacturing community. In ATHENA, EADS Research Centre is involved on several projects (Dynamic Requirement Definition, Pilots, ATHENA Interoperability Framework) and groups (Technological group and End-User Watching dog group), with as objectives to identify interoperability needs, to product requirements and finally to evaluate, test and benchmark the ATHENA results.

In order to achieve objectives of ATHENA in term of impact and representation, the **business needs** were collected from EADS Research Network (constituted by several Business Units of EADS like Airbus, EADS Launcher vehicles, Astrium, Eurocopter…), major Aeronautic Research Programs (VIVACE) but also from the manufacturing community through ISO SC4 TC184, OMG Mantis Technological Group, AFNOR, MICADO, AFNET.

The **requirements** were derived from these needs. They were elaborated on the basis of anterior Research Projects results (what is working, what is not satisfying) related to "Product Data Exchange and Sharing" for "Collaborative Product Development" within a Virtual Organization (AIT, RISESTEP, SAVE). They were analyzed and generalized with other requirements coming from other communities (Enterprise Modeling,

Ontology, Executable Business Process, Service Oriented Architecture, Model Driven Approach) and sectors (automotive, telecom, furniture…) in order to extract interoperability issues to be addressed by the different ATHENA research projects.

The **pilot** for Collaborative Product Development was elaborated in order to implement a representative business case, in term of general business needs and requirements of the manufacturing community - integration of the legacy system, reuse of STEP application protocols, support of change and configuration management workflow processes across heterogeneous organizational and ICT boundaries (DIECOM) – and in term of functional scope of ATHENA – interoperability solved by simultaneous usage of enterprise modeling, knowledge modeling, innovative ICT technologies and ontology domains.

Or enterprise level of maturity and awareness related to the different involved domain is usually not very important today, as used approaches are emerging and innovative approach. For example, concerning enterprise modeling, different level of maturity and way to measure them was stated in ATHENA A1 project. Similar criteria and measure of maturity are also defines for other domains as CMM for software engineering or PLM. One difficulty for pilot elaboration is consequently to allow enterprises to validate that ATHENA research results match to their needs, without being sure that the minimum required knowledge of the implied domains exists within the enterprise. ATHENA training activity is consequently of a prime importance to support ATHENA piloting activity, in particular elaboration of the pilots. It was required for Collaborative Product Design pilots establishment to reach sufficient level of knowledge in order to propose accurate to-be scenarios that take advantage and implies approaches coming from the different ATHENA domains, i.e. enterprise modeling, collaborative process modeling, Service Oriented Architecture, Model Driven Approach and ontology.

In addition, the level of sector-related knowledge of most of researchers in the different implied domain is weak. For example very few are aware of or concerned by manufacturing application protocols, change and configuration management, product data management or product life-cycle management. All these topics are nevertheless very important. From a prospective point of view, they have to be integrated within to to-be scenarios targeted by the ATHENA Collaborative Product Development pilots. It is required to provide to the researcher and to the different interoperability actors and stakeholders the sufficient level of knowledge to really understand role of Product Lifecycle Management, Product Data Management and Product Data Exchange and Sharing for efficient collaboration required for Collaborative Product Design.

This paper presents part of the Research performed by the author during the last two years under the umbrella of ATHENA program piloting activities, in relation with cluster of international projects (i.e., AIT, RISESTEP, SAVE, ENHANCE, VIVACE, ISO SC4 TC184 working groups, IDEAS) which resulted in a set of to-be scenarios and proposed pilots infrastructures for Collaborative Product Design and implied enterprise applications.

1. PILOT DEFINITION PREPARATION

1.1. Interoperability problems analysis and Business needs definition

Analysis of interoperability problems was initiated within the IDEAS roadmap project, with as a result several documents describing the kind of ecosystems concerned by interoperability and accurate FP6 instruments to support implementation of IDEAS research roadmap.

These IDEAS documents were reused and refined for elaboration of Dynamic Requirements Definition Process in ATHENA B4 project, in particular within the interoperability patterns section.

They were also used for the structure of business as-is and to-be scenarios specific requirements and needs collection, in particular through a map of interoperability actors and stakeholders for technical enterprise applications interoperability used to structure.

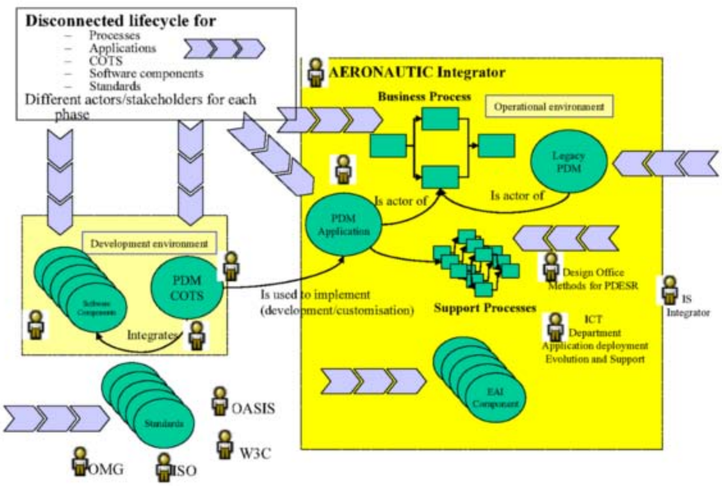

Figure 1: Actors and stakeholders for interoperabilty

A very important point reflected during requirements definition is the fact that, in an industrial context, the clients for interoperability solutions are not only the classical “end-users” of a software application, but also “Process and Methods” departments of the Design Office, IT departments that ensure support for Collaborative Product Design applications definition and software selection, Standardization bodies and Software Product providers and software architects/developers. More then clients, they are also interoperability actors and have all a role for final interoperability of resulting operational systems that is to be addressed during specification, design, development, deployment and operational support of these systems.

The needs were consequently collected from each category of implied actors and categorized according a classification of these actors.

1.2. Interoperability Requirement Elaboration

Other important pattern concerns software product viewpoint against applicative system viewpoint. For an applicative system that is fully developed for an enterprise that pilots a dedicated project, requirements are coming from this enterprise. When using software product components, the situation is very different as requirements are coming from the marketing department.

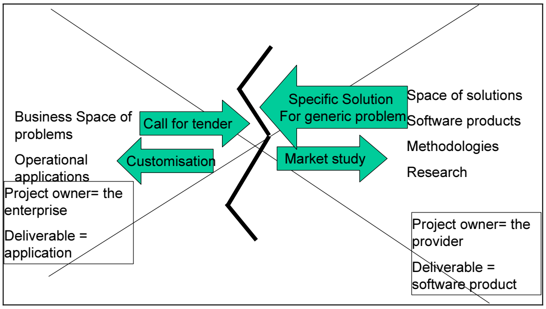

Figure 2: Application project against software product for establishment of requirements

Within ATHENA, as within a networked organization, the different implied applications are based on requirements coming from multiple stakeholders: the industrial partners for multiple sectors (Automotive, Furniture, Aerospace and Telecom) and applications (Collaborative Product Development, Supply Chain Management, Portfolio Management) but also clients and experts of the ATHENA domains dedicated technology providers. Finally, innovation and scientific excellence are constraints of prime importance as ATHENA is a European Research Program.

It is the reason why Dynamic Requirements Definition Principles and processes were defined, with a process allowing to elaborate specific requirements from specific business scenarios, and then to analyze and generalize them in order to extract common ATHENA requirements for interoperability. Generic solutions are developed in order to respond to the ATHENA requirements, which will lead to generic and specific IT products.

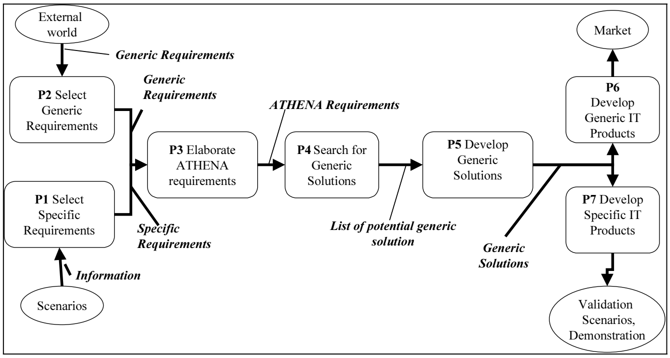

Figure 3: The ATHENA Dynamic Requirements Definition Process

Next important point to consider is that solutions provided by ATHENA are not developed from scratch and have to be deployed within an existing context: legacy applications and Information System Department policies are to be considered, as current technological frameworks (WEB services, application servers, web servers, WEB 2.0, Model Driven Architecture) and standards under development by different communities. ATHENA solutions have consequently to be composed with components coming from the outside of ATHENA in order to global and satisfactory solutions that can lead to pilots.

Pilots scoping is consequently defined according common ATHENA requirement that are of prior importance, according the decisions made by the consortium, and according the level of expectation for the targeted sector (Aerospace in our cars) in order to support current challenges and objectives for the next years. It also has to be defined in order to integrate current best practices and available functional implementations in order to provide an infrastructure with a sufficient quality in order to perform the pilots.

An important prerequisite, in order to define the pilots with accurate functional architecture and technical infrastructure, was the inception of the different implied domains.

1.3. Targeted high level solutions in ATHENA

ATHENA aims to address interoperability at all the layers of the enterprise: enterprise, knowledge and Information./Communication Systems.

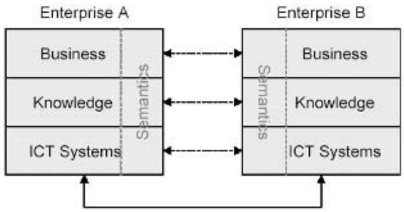

Figure 4: Interoperability supported at all the layers of the enterprise by ATHENA

To do so, ATHENA research projects (Action line A) were defined in order to address:

- Enterprise Modeling in the Context of Collaborative Enterprises (project A1)
- Cross Organizational business process modeling and execution (project A2)
- Knowledge Support and Semantic Mediation Solutions (project A3)
- Interoperability Framework and Services for Networked Enterprises (project A4)
- Planned and Customizable Service-Oriented Architectures (project A5)
- Model-driven and Adaptive Interoperability Architectures (project A6)

Project A4 is the "integrative" project that should provide a global framework to integrate the results of the different other projects. Link is performed with communities building through Cross Action line Teams and implementation of the Dynamic Requirements Definition Process.

In such a context, the pilots were defined in order to take advantage, when defining the to-be scenarios, of enterprise modeling in the Context of Collaborative Enterprise (Collaborative Product Development Network governance), Cross Organizational Business Process modeling (Change and Configuration Management workflow across a virtual organization), Knowledge Support and Semantic Mediation (Product data exchange and sharing between heterogeneous organizational and technical boundaries).

Link with Information and Technology actors is targeted by project A5 (Planned and customizable Service Oriented platform as execution platform for models design and operations) and project A6 (Model-driven and Adaptative Interoperability architecture that should allow to organized the models as their relation with modeling and execution platforms components).

This evaluation of A5 and A6 results is addressed within the piloting activities by the development of a Collaborative Product Development Infrastructure, shared by the different targeted business scenarios, and that will allow to evaluate federation of ATHENA solutions (federation is used for fast and highly reconfigurable interconnection) and integration with legacy technological and sectors' platforms (Service Oriented Platforms as CORBA, WEB services, Application servers…) and standards (Manufacturing application protocols as those provided by ISO STEP or ICT standards as OWL or UML).

1.4. Technological domains inception

Researchers involved in ATHENA and involved in the different research projects have different backgrounds in term of paradigms, technologies and focus. For example experts involved in Semantic Mediation are working in the domain of ontology, with a deep knowledge of existing problematic (e.g. ontology coherency, inference, reasoning), approaches (ontology design) and tools (e.g. Ontology Web Language, Jena…). Experts involved in Service Oriented Platform elaboration are working in the area of WEB services, with a deep knowledge of existing architectures components (WSDL, SOAP, XMLSchema…). Experts involved for Model-driven and Adaptative Interoperability architecture are very familiar with Software engineering methodology, UML cases, Model Driven Architecture, Meta object facilities… But when willing to federate these different approaches, each expert in one domain is a new comer in the other domain. As the different communities are not always willing to work together outside of ATHENA, a particular effort is required from an expert to take some distance from is domain of expertise and to think in term of holistic approach.

Other categories of "new comers" in ATHENA are Industrial partners initially involved in the project and people invited to contribute to piloting activities. They most of the time have very few knowledge concerning all the domains implied in ATHENA. An important challenge in ATHENA, when defining pilots, is to be able to quickly incept the fundamentals of each of these domains and how they can be used together to define a holistic

and global solutions that is satisfactory and useable by the different actors of the interoperability chain, and that includes the experts of the different research projects in ATHENA.
In order both to orient and weight importance of the requirements and solutions, and to define accurate pilots for results demonstration and evaluation, it was consequently required to develop a sufficient knowledge of the different involved domains. This was particularly important in order to insure impact of the ATHENA results both in user communities (utility) and scientific community (innovation).

As pilots target holistic solutions, an important risk exist if some important components awaited from research project is not delivered or not of sufficient quality for usage or integration. The knowledge to develop was consequently not only in term of concepts and approach, but also in term of existing alternative and useable solution components in the context of the pilots. Advantage of developing this knowledge was also to be able to challenge and to benchmark that ATHENA solution components and to evaluate the real level of innovation of the different research project.

For inception of the different domains, EADS CCR realized different technological studies in order to understand fundamentals of each domain and how it can be used in the global interoperability chain (it means from application or software product specification to the deployment and operational support). More important, facing some overlapping between the different existing technological frameworks and standards, this exercise was of particular importance in order to use them together an accurate and non-artificial way within the pilots. For example, how to justify and manage simultaneous usage of ontology in OWL (Ontology Web Language from W3C that is an identified layer for the A3 Semantic Reconciliation Project in ATHENA), application models in UML (Unified Modeling Language from Object Management Group that is one of the building components of the A6 project in ATHENA), process models in BPMN (Business Process Model Notation from Object Management Group that is potential candidate for modeling in A2 Collaborative Business Process ATHENA Project), workflow models in XPDL (XML Process Definition Language from Workflow Management Coalition that was identified as an important standards for EADS CCR requirements) and enterprise models in POP* (Process Organization People defined in A1 Enterprise Modeling ATHENA project) an efficient way? What will be the driving paradigms?

The different studies performed by EADS CCR were the following one.

First a comparison was performed between ISO STEP technological framework and Ontology technological framework for semantic reconciliation, leading to proposal of a mapping and development of a tool, the STEP mapper, to implement transformation according this mapping. The STEP mapper is one component for the Aerospace pilots that allows to reuse Manufacturing application protocols as ontology of reference for the semantic mediation solutions proposed by the A3 project. It was also the opportunity to understand the fundamentals of ontology. Finally it allows identification of some issues for technological integration.

Second a study was performed about open source case tools implement Model Driven Approach and integrating Meta Object Facilities and their usage to generate Platform Independent Model based on existing STEP Application Protocols and Product Lifecycle services definition (PLM services from OMG Mantis workgroup), to define them a Platform Specific Models using stereotyping dedicated to generation on Service Oriented Platform components. From the study, different components of the piloting infrastructure were defined and deployed as the PLM server of reference defined by the XPDI project. Some MDA case tools with associated cartridge for generation of code in various existing open source Service Oriented execution platform were identified as AndroMDA, OpenMDX or EclipseEMF. These tools are identified as alternative solutions components and targets for the ATHENA results coming from Action line A. The study was also the opportunity to identify some issues concerning MDA standards, as quality of the implementation of the OMG specifications by the existing tools, being commercial or open source. For example all the UML tools don’t support all the constructs for UML profiling (as tagged values), as it illustrated by AndroMDA solution. Exchange of models based on XMI is most of the time a nightmare (for example let’s try to interchange models between Rose, Poseidon, ArgoUML and MagicDraw). Finally some alternatives of MOF exist that are supported by active communities as EMF for the Eclipse community or GME. As a result, to identify the set of modeling tools and to defined rules for architectures for standards of reference with the Collaboration Space for Collaborative Product Definition is of prime importance.

Finally a study was done in order to identify the targeted execution platform components to use in the piloting activities, with as constraint adequacy with Service Oriented and Model Driven approaches, conformance with open standards, industrial quality and finally free availability (for resource constraint within ATHENA and for accessibility to Small and Medium Enterprises). Within the community, several kinds of components were identified. First application servers, based on Enterprise Java Beans specification or CORBA Components Model specification, were identified as key components. Open source and free implantation of quality exist, as JBOSS, Jonas or OpenCCM. Finally several commercial or free open source case tools propose PSM profiles for code generation on such platforms. Other important components are portals. Portal address problematic of nomadic applications (access is performed by different heterogeneous clients in term of software and hardware). They address the presentation part of n-tiers application, and can be connected easily to

application server. Maturity of portal is today important, as existence of several implemented standardized specifications (JSR168, WSRP) demonstrates it. Such components allow syndication of content on the desktop of the user, hiding complexity of the underlying solutions. Finally the WEB2.0 current trend, with several technological platforms (JSF, STRUTS, XUL, XAML…), allows using Model Driven Approach not only to define automatically service but also their user interfaces. Some examples exist, as the BPM4STRUTS cartridge for AndroMDA.

The different performed studies allowed to identify some of the piloting infrastructure components for modeling and execution platforms, to evaluate state of the practice concerning the different domains implied in ATHENA and to identify alternative solutions for ATHENA solutions benchmarking and eventually replacement to face the risk of integration of the different demonstrators provided by ATHENA research projects.

2. PILOTS DEFINITION

2.1. The principles

Aerospace pilots for Collaborative Product Development were defined according the following principles and constraints:

1. Pilots are aiming to demonstrate targeted to-be business scenarios to support collaboration in networked organization willing to define a product, and to prove that the ATHENA solutions will make it possible and efficient to support Aeronautic domain challenges (Virtualization of the enterprise and virtualization of the product in order to lead to more competitive products and organization).
2. Pilots are aiming to demonstrate workable solutions in operational environment, with Enterprise applications. Consequently the different software components should be of sufficient quality in order to allow easy evaluation by member of the pilots. In such a situation, demonstrators selected to be evaluate within the pilots should be of a sufficient quality in order to be considered as prototypes (and not as simple demonstrators).
3. The software components used should not be specific and accessible by ATHENA actors and by the community during the ATHENA project and after the ATHENA project. Consequently open components based on standards and freely available will be preferred to specific components that are not freely available, when having expected level of quality in term of performance and in term of respect to the standards. Respect of the standards is a guarantee for interchangeability of the components. In particular, the idea is to allow to enterprise willing to use ATHENA results to select their own components, without as few constraints at possible. For example, willing to choose an application server, compliance with EJB specification will allow selecting as execution platform or JBoss, or Jonas, or Websphere. For code generation , any transformation case tool will be usable when supporting standardized EJB profile and generic transformation to any compliant EJB platform.
4. Pilots are targeting to demonstrate solutions dealing with:
   * Enterprise Modeling in the Context of Collaborative Enterprises
   * Cross Organizational business process modeling and execution
   * Knowledge Support and Semantic Mediation Solutions
   * Interoperability Framework and Services for Networked Enterprises
   * Planned and Customizable Service-Oriented Architectures
   * Model-driven and Adaptive Interoperability Architectures

   and to evaluate innovation of ATHENA proposed solutions and adequacy with business requirements
5. Pilots are to be designed in order to achieve the ATHENA program objectives in term of impact on the community. In particular close connection with main ATHENA results and availability of connected training material is of prime importance.
6. Pilots are to be designed in order to easily support analysis of results, to provide feedback to the researcher and to provide next set of requirements for interoperability.

In order to respect these principles, EADS CCR defined three pilots with a common organizational and technological infrastructure for the 3 pilots.

Within the to-be business scenario, it is assessed that enterprise networks will be created to design products, and that they will be supported by an organization providing services for collaboration and interoperability establishment.

This organization will fist have to be set-up, and will have to defined the proposed service. They will have to define and manage the members of the network, and propose an instrumented process to allow each member to enter, participate and leave the network.

They also will have to propose collaboration process of reference, that are common to any members of the network, that are public, and that may be connected to member private existing processes.

In addition, it should be possible to enact these processes with interacting enactment engines. Finally, the data flow between organizations and applications will have to be supported (here it will be product data) with services for transport and semantic reconciliation of the heterogeneous information bases existing locally for each network member.

The Collaborative Product Design organization will also have to provide services concerning setting-up, management and governance and a network. Finally some services concerning active network knowledge modeling and execution will also be expected.

A demonstration scenario was defined for the pilots, with a network, a collaboration process, set of applications, a test collaboration scenario and software infrastructure.

2.2. The Network

In addition to the Collaborative Product Design organization, two members were considered: EADS organization as OEM and integrator, and Landing Gear Organization, as an equipment supplier. As it is a network of enterprise, this model can be extended to more partners, risk sharing partners or sub-contractors from different layers. For the pilot purpose and ATHENA result evaluation and demonstration, two partners are nevertheless sufficient in a first stage.

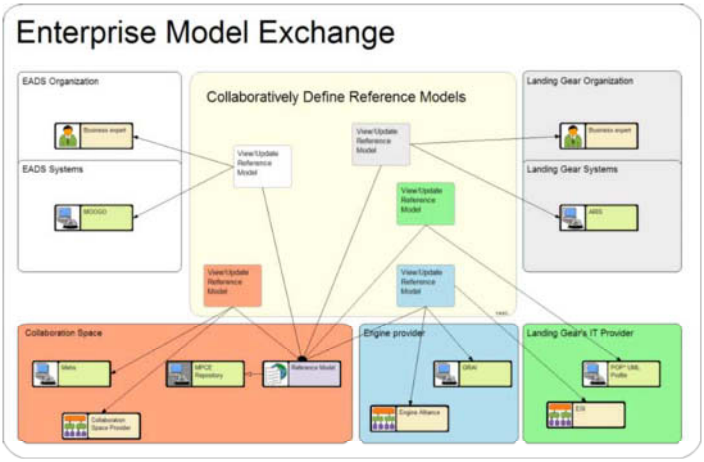

Figure 5: network defined for the model

2.3. The product and industrial project, the virtual Space Bird

The network is working in a project called the virtual Space Bird. The product structure is managed by EADS within its own Product Data Management system. The product structure of the landing gear, that is a off-the-shelves equipment, is managed within the PDM system of Landing gear Organization.

Designers of respective Design Office of the two organizations, have to collaborate during detailed design phase of the virtual space bird. It is the case in particular for Dominique Dupont (EADS) and Jane Doe (Landing Gear Inc.), who have to instruct a change request concerning adaptation of the landing gear system to a request to augment the weight of the Space Bird. As for all industrial organization, it implies to follow change management and configuration management processes. Internally, these processes are defined by Design Office of each organization. Externally, the change management process is defined at the network level.

2.4. The Change Management Process

The concerned change management processes for each organization and for the collaborative shared space (as public and shared process for all members of the network) were formalized, in order to be compliant with CMII industrial quality standard (Configuration Management II).

They were modeled with Shark tool, that implements Workflow Management Coalition standards, and are available as XPDL files. They were also modeled using other tools used in ATHENA as Mo2Go, Metis and Maestro. The distinction was made between local views of the processes and public view of the processes. In the collaboration space, a mapping is required between participants (person, organization, applications), and between workflow relevant information.

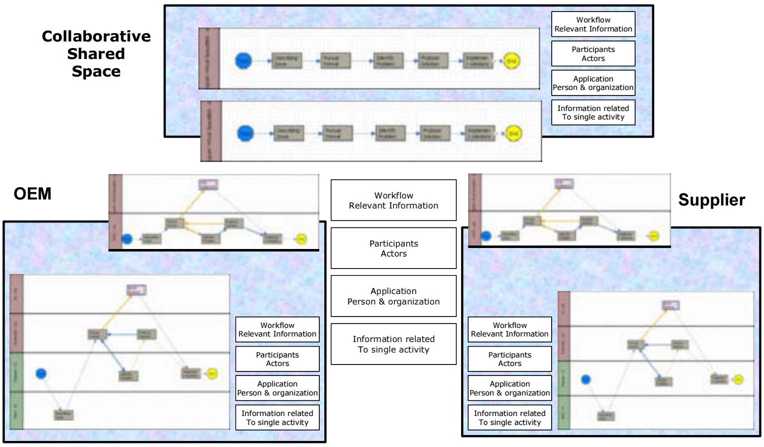

Figure 6: Process view of the collaboration - change management

2.5. The applications

In order to define implied application, a functional view was first elaborated for each business cases. For the Interconnection of process, the defined functional view is the following:

- For collaborative shared space, PDM repository (with associated PLM services) and workflow enactment services are provided, plus user faced services for visualization and monitoring.
- For each member, a Product Data Management system including a workflow system is available

The same definitions exists for the different pilots, but are not detailed in this paper (c.f. Athena Aerospace piloting WEB site to have access to these views).)

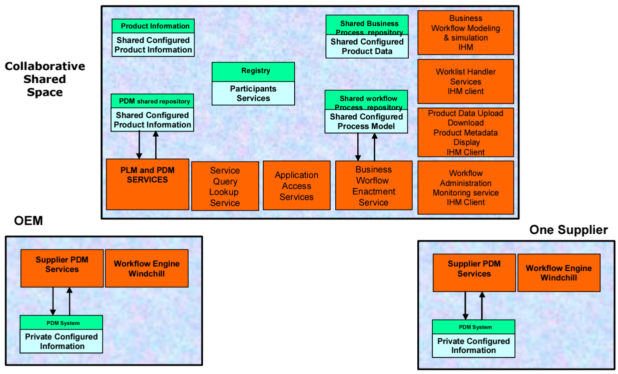

Figure 7: Functional view of the collaboration space

2.6. The software infrastructure

For each functional applicative view, several ICT views were defined with alternative potential solutions, coming from ATHENA or coming from the outside. For example, for process interconnection, workflow solutions implementing Wfmc specification were identified as potential alternative solution for Maestro and Nehemiah developed in ATHENA project A2.

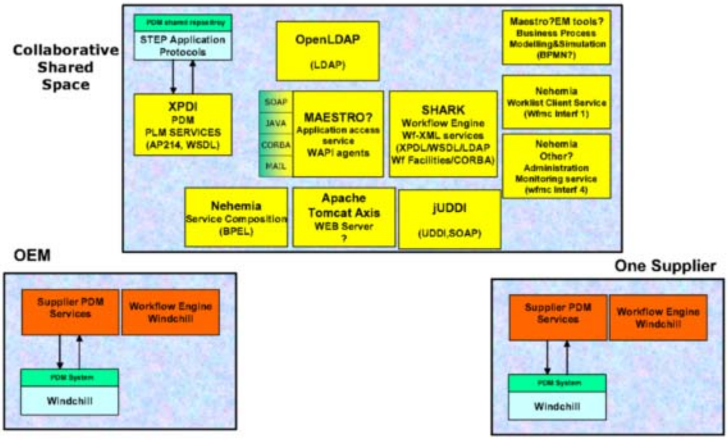

Figure 8: ICT view of the collaboration space

As for functional views, ICT views were defined for all the pilots.

2.7. Test collaboration scenarios

As it is an industrial business scenario, several collaboration test scenarios were defined in order to address the different levels of organization (individuals, organizations, enterprises).

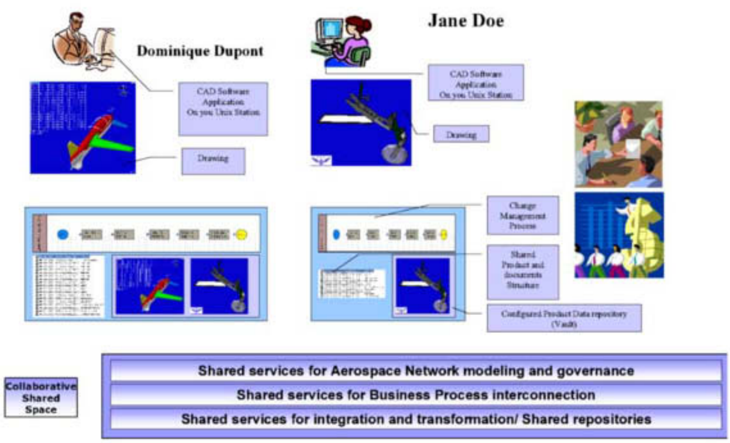

Figure 9: individual, organization and enterprise levels

At enterprise level, it is first required to establish the requirement space. Definition and design is to be performed by Networked Organization Collaboration Space Architect and Consortium behind the network, by means of Enterprise Modelling tools. Then the development is to be done by ICT people by means of standards, software engineering tools and Commercial of the shelve software. Finally the collaboration space is to be exploited, maintained adapted by Networked Organization Managers and ICT people by mean of governance tools.

At organisation level, one member of the network should be able to join, participate and leave the network. For joining, it is required to first to identify the B2B processes to be plugged on the collaboration space (by business people, in our case the change management process). The different required mapping (process, roles, actors, tasks, stakeholders, objectives…) are to be done by business and disciplines experts, by means of modelling-mapping tools for enterprise/business models. It includes enterprise modelling tools and software engineering tools. Finally the implementation of the mapping is to be done by developers (not traditional, those using, parameterising and controlling execution of services provided by ATHENA for transformation, negotiation…). For leaving the network, the organisation and application will have to be disconnected and removed from network repositories.

At person level, the participation to the network organisation will consist in launching instances of collaboration processes. A precise scenario was defined for an instance of the change management process in the context of the virtual space bird design, associated to a concrete product structure of the space bird (detailed definition is available on the ATHENA Aerospace pilot WEB site).

3. PILOT DEVELOPMENT AND EXECUTION

3.1. Component solution deployment, integration and inception

EADS CCR played the role of the Collaboration Space Organization, defining a collaboration space, its functional services, and then identifying and evaluating solutions implementing these functions.

A list of 80 software components to evaluate was defined, including all the ATHENA demonstrators (e.g. Maestro, Nehemiah, MPCE…), preexisting tools (commercial or not) required for the collaboration space (e.g. enterprise modeling tools, software modeling tools, Product Management Systems…) and alternative solutions coming from the community (e.g. Enhydra Shark and Jawe, AndroMDA…).

The evaluation concerns the functional coverage, the workability and integration capacity according the different interfaces to use: POP* for enterprise models, PIM4SOA for application and service modeling, WSDL and XML schema for interconnection between modeling platforms and execution platforms. The evaluation also concerns deployment and parameterization within an operational B2B context (accessible across the WEB taking into account security policies implement through firewalls and internet restriction access on the WEB).

This is a heavy task, with numerous feedback to the demonstrator providers to fix bugs or interoperability issues.

3.2. Application set-up

Once validated, the components are deployed on the ATHENA aerospace piloting WEB site as accessible tools, services and operational data and models, in order to be able to play the scenarios at individuals' level.

Currently, very few ATHENA components were deployed on the WEB site (Jonhson and Lyndon only, for a non definitive version).

The XPDI PLM server of reference was deployed and Virtual Space Bird Model was put on line.

Finally some application server and portal are being deployed.

3.3. Scenario playing

Scenario playing will be performed once a complete configuration will be fully validated, deployed and set-up. It is the target for the last year of ATHENA, with results in October 2006.

CONCLUSION: ATHENA PROGRAM AS INTEROPERABILITY LAB WITH EMERGENCE OF TOMORROW'S SOLUTIONS

Through the pilot elaboration and deployment, ATHENA appears as very interesting interoperability labs: all the stakeholders and actors for interoperability are represented within the program and are working together to implementation of the pilots. It allows a kind of internal competition between several approaches that are experimented through piloting activities.

Inception performed by EADS CCR allowed to identify the interest of emerging technologies and approaches (Service oriented Modeling, Enterprise Modeling, Ontology, WEB services ,Model Driven approach) to establish a collaboration space infrastructure for Collaborative Product Design with a virtual and networked enterprise. Ontology are of particular interest to produce semantic models that can be logically validated (that is not the case with usual modeling tools based for example on UML or Express). Then UML case tools are of

particular interest to establish annotation of models to generate applications and services on targeted preexisting execution platforms that are service oriented. Finally service oriented execution platforms are of particular interest to interconnect software components used for applications (Enterprise Application Integration), presentation (Nomadic application – e.g. by means of portals and WSRP) or modeling (model sharing or exchange, interconnection between modeling platforms and execution platforms to reflect concrete solutions within the models).

The challenge of the last ATHENA program year will be to select the more promising solutions in ATHENA and to lead the pilots to the end, with a complete platform for the collaboration space.

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Wavelets to Enhance Computational Intelligence in Computer-Aided Engineering

Hojjat Adeli
Lichtenstein Professor
College of Engineering, The Ohio State University
470 Hitchcock Hall 2070 Neil Avenue, Columbus, Ohio 43210, U.S.A.

Abstract. Concurrent engineering (CE) is intertwined with the field of computer-aided engineering (CAE). The author presents a vision of future for CE and CAE where computational intelligence (CI) will play an increasingly significant role. Various disciplines within CE such as design, manufacturing, knowledge management, collaborative computing, Web processes and services, and distributed infrastructures must rely heavily on CI to achieve the increasing sophistication demand. The author has been advocating and advancing a multi-paradigm approach for solution of complicated and noisy computational intelligence problems. In 1995 he co-authored *Machine Learning - Neural Networks, Genetic Algorithms, and Fuzzy Systems* [1] the first authored book that presented and integrated the three principal soft computing and computational intelligence approaches. It was shown that such integration would provide a more powerful approach than any of the three approaches used individually. Since the publication of that ground-breaking book the author and his associates have demonstrated that chaos theory and wavelets can be used to further enhance computational intelligence especially for complicated and noisy pattern recognition problems. In this lecture it is shown how wavelets can be used as a powerful tool to complement and enhance other soft computing techniques such as neural networks and fuzzy logic as well as the chaos theory for solution of complicated and seemingly intractable CI problems. Examples of research performed by the author and his research associates in the areas of intelligent transportation systems [2-4], vibrations control [5-8], and nonlinear system identification [9-10] are presented.

Keywords. Chaos theory, computer-aided engineering (CAE), concurrent engineering (CE), fuzzy logic, intelligent transportation system, neural networks, wavelet

Biosketch: Hojjat Adeli is Professor in the Departments of Aerospace Engineering, Biomedical Engineering, Biomedical Informatics, Civil and Environmental Engineering and Geodetic Science, Electrical and Computer Engineering, and Neuroscience at The Ohio State University. He is also the holder of Lichtenstein Professorship. He has authored over 400 research and scientific publications in various fields of computer science, engineering, and applied mathematics since 1976 when he received his Ph.D. from Stanford University at the age of 26. He has authored ten books including Machine Learning - Neural Networks, Genetic Algorithms, and Fuzzy Systems, Wiley, 1995, Neurocomputing for Design Automation, CRC Press, 1998, *Distributed Computer-Aided Engineering*, CRC Press, 1999, *Control, Optimization, and Smart Structures - High-Performance Bridges and Buildings of the Future*,

Wiley, 1999, and most recently *Wavelets to Enhance Computational Intelligence*, Wiley, 2005. He has also edited twelve books including *Knowledge Engineering - Vol. I - Fundamentals* and *Vol. II -Applications*, McGraw-Hill, 1990, *Intelligent Information Systems*, IEEE Computer Society, 1997. He is the Founder and Editor-in-Chief of the international research journals *Computer-Aided Civil and Infrastructure Engineering*, now in 21st year of publication and *Integrated Computer-Aided Engineering*, now in 14th year of publication. He is also the Editor-in-Chief of *International Journal of Neural Systems*. In 1998 he received the *Distinguished Scholar Award* from The Ohio State University "*in recognition of extraordinary accomplishment in research and scholarship*". He has presented Keynote Lectures at 57 conferences held in 33 different countries.

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Visual Reasoning, an Underlying Cognitive Element of Design Creativity, and its Intelligent Tutoring System

Yong Se KIM[1]
Creative Design and Intelligent Tutoring Systems Research Center
Sungkyunkwan University, Korea

McKim viewed the design ideation process as composed of the iterative interactions of the following three processes; *imagining* process to synthesize in mind, the *drawing* process to represent the synthesis results, and the *seeing* process to analyze the drawings. The nature of design reasoning as the iterative process of seeing-moving-seeing has also been discussed by Schon. As design tasks often involve spatially structured objects and physical spaces, visuo-spatial aspects of the above design ideation process are naturally emphasized. Yet, we believe this design ideation process is essential for all kinds of design tasks. The ability for this design ideation could be enhanced through suitable trainings where visuo-spatial aspects could be used to lead this ideation process in more natural ways.

With the above intent, we define *visual reasoning* as an iterative process composed of visual analysis, visual synthesis and modeling so that these three would account for seeing, imagining and drawing, respectively, in a more visuo-spatial way from the context point of view and in a more flexible way from the methodological way. A typical problem for visual reasoning could be the missing view problem, which requires visually constructing a valid 3-D solid object by analyzing two 2-D orthographic projections. Note that due to the incompleteness of the constraints given with two orthographic views, there are multiple solid objects satisfying these geometric constraints. Thus, the solution process requires visual synthesis with partial clues and corresponding internal and external representation of the synthesis result in order to go through the next reasoning step starting with visual analysis. We found out that visual reasoning ability is closely related with underlying cognitive ability in design creativity.

We are building an intelligent tutoring software system to help learning this visual reasoning in a personally customized manner for individual learners. *The Intelligent Visual Reasoning Tutor* (IVRT) has two levels of intelligent tutoring functions. Intelligent critiquing and adaptive hint generation capability address individual problem solving processes based on geometric reasoning. Learning contents are adaptively provided based on student assessment and customizable teaching strategies.

In this presentation, we will discuss visual reasoning as an underlying cognitive element for design creativity and its intelligent tutor system as well as some experiment results and implications for design learning and education.

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[1] Yong Se KIM, School of Mechanical Engineering, Sungkyunkwan University, 300 Chunchun, Jangan, Suwon, Korea, 440-746; E-mail: yskim@skku.edu.

Supporting System for Design and Production with Sharing and Access of Product Failure

Kazuhiro AOYAMA[1] and Tsuyoshi KOGA
Department of Environmental & Ocean Engineering, School of Engineering, The University of Tokyo, Japan

Abstract. Since the product recall problem is recently observed, realizing design and production activities which can prevent occurrences of a product failure has been becoming a serious issue. This paper proposes "the Synthetic design approach of a product and a production process which enables to reduce occurrences of a product failure from the initial stage of a product development". In order to realize this proposed concept as a specific system, the integrated model of the failure information in the design and production is introduced. This paper shows some examples of design and production for a circuit breaker and an automobile with considering a design error and a production failure using developed prototype system.

Keywords. Product Failure, Production Failure, FTA, FMEA, System Integration

Introduction

Since the product recall problem is recently observed, realizing design and production activities which can prevent occurrences of the product failure has been becoming a serious issue. On the other hand, in the manufacturing industry, they make efforts to develop the PLM (Product Lifecycle Management) system that can manage engineering information from the product design to a production and also maintenance, and scrap. This PLM is based on digital engineering technology, such as CAD and CAE, and this system realizes sharing of the various information that many engineers engaged in a design and production need by using PDM (Product Data Management).

An information management system is utilized and huge efforts are paid to realize a product quality with that a failure does not remain. However, in the life cycle of a product development, there are many reconsidering activities by various failures and the corresponding failures and radical actions to remove failures are demanded. In this paper, we re-acknowledge a current matter derived from such a situation, we aim at arguing about the structure of information management to get the competitiveness that can reduce product failure occurrences in the manufacturing industry as much as possible, and can respond to QCD (Quality, Cost, Delivery) that are three important demands of a market [1][2].

[1]Corresponding Author: Associate Professor, The University of Tokyo, School of Engineering, 7-3-1 Hongo, Bunkyo-ku, Tokyo, Japan 113-8656; Email: aoyama@naoe.t.u-tokyo.ac.jp

1. Approach of Failure Prevention in Product Development

1.1. Failure Prevention in Information System

Recently, in a product design and a production, an information system has very important role. It manages the huge information related to a product design and production appropriately, and new information systems, which can utilize cases of past success, failure and etc., are tried to develop. The most of them are called a knowledge management system; there are activities for formalizing an engineer's tacit knowledge and enabling to cooperate with design system and production system closely. Although we have various methods for those activities, the mechanism of preventing failure happening etc. is proposed and used by providing effectively the accumulated case information, which is digitalized, to an engineer [3].

Concerning prevention of a product failure before it happens, it is pointed out that an initial development stage has an important role to consider a product. However, there are not many reports that have realized incorporating failure considering from the initial development stage and utilizing the considering result efficiently to the later stage. Although it can be recognized that failures and product functions are inextricably linked, the expression of a product function becomes so difficult according to the earlier development stage that it is very hard to consider a product failure in an earlier development stage [4].

Besides, although there are many proposals concerning failure considering in a production process, there are few examples that have realized systematic description of a quality problem. There are few information models which can express appropriately the relation that exists between the function of a product, and a behavior/structure and a production. It can be understood that synthetic considering of product failures from a design to a production is not realized for the above reason.

1.2. Synthetic Management of Failure Information in Design and Production

This paper proposes "the synthetic design approach of a product and a production process which enables to reduce occurrences of failure from the initial stage of development" as one approach for solving the above-mentioned subject. In order to realize this proposed concept as a specific system, the integrated model of the failure information in a design and a production, which is mentioned later, is introduced, and the following items from a) to d) are realized.

a) Realization of the stepwise design approach with expression of a designer's thinking process.
b) Realization of the failure reduction approach in a product design by a modeling of failure based on a product behavior.
c) Realization of the failure reduction approach in a production process design by a modeling of a production process with considering a product quality.
d) Realization of a failure knowledge database.

2. Integration of Design Error and Production Failure

2.1. Model of Design Error and Production Failure

A failure mechanism is proposed in order to represent and to share the product failure from the design stage to the production stage. An integrated model of a design error and a production failure provides the causality between a design error and a production failure. A product failure model to describe errors and failures on the design stage is proposed using a model of intended and unintended product behavior. A product failure model on the production stage is proposed using an operation model and an production quality model as shown in Figure 1. An integration of an product design failure model

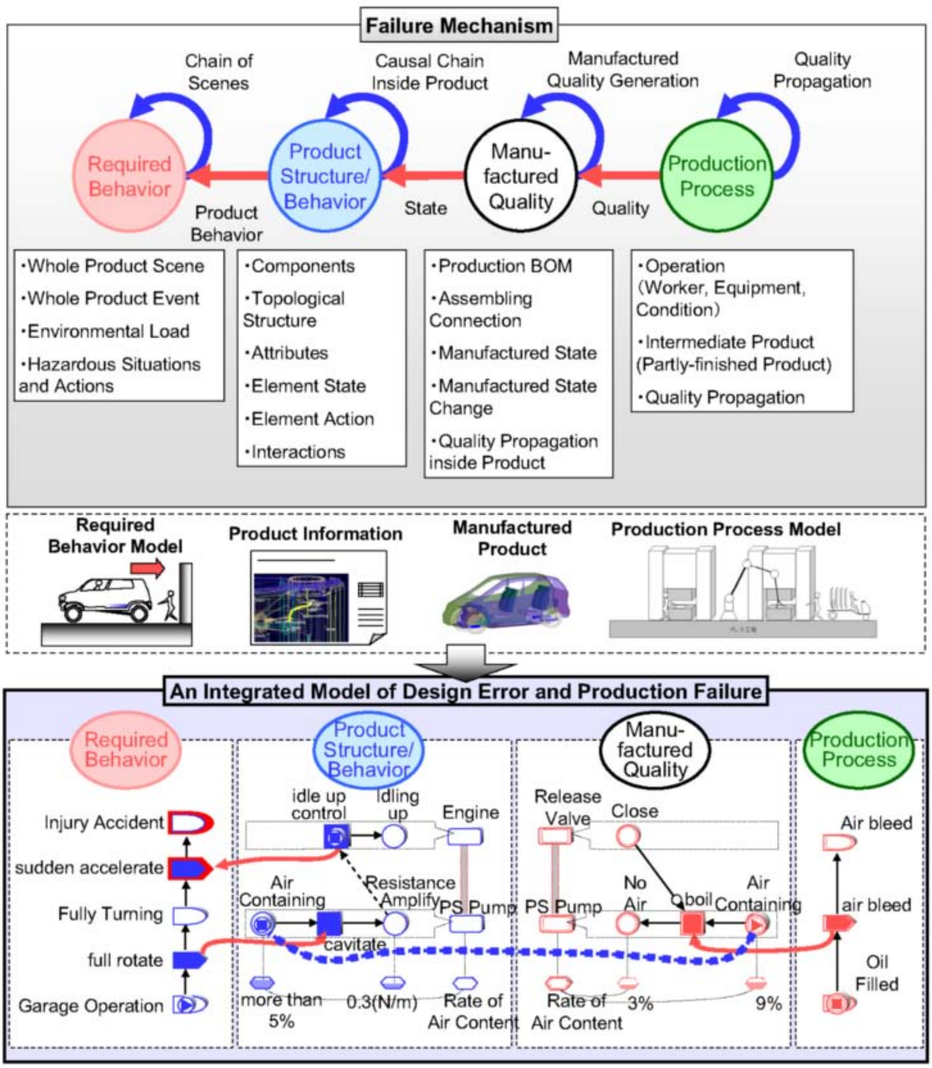

Figure 1. An Integrated Model of Design Error and Production Failure

and production failure model, the causality between the design stage and production stage can be described. By this integrated model, both of a product design system and production system that can share and access the following failure information is achieved;

- An model of required behavior, product structure and product behavior
- The quality for manufactured product, M-BOM structure (Manufacturing Bills Of Material), and operational sequence of production process.
- A design process model of product and production process in order to reduce the product failure
- Product failure database system for information sharing and access.

2.2. Interface Design in order to Achieve Required Behavior

The product failure on the design stage is defined as ‘a lack of required behavior’ and ‘an unexpected behavior’ by the introduction of the product behavior concept. Hence, the failure reduction on the product design stage can be defined as a product design with high achievement level of required behavior, and less unexpected and hazardous product behavior.

An interface design is very important, because it determines the whole product behavior. The interface is defined as the interactions between product components. Hence, an interaction design method is proposed by the comparing two models: 1) required behavior model and 2) product behavior and structure model. The interaction design, that can achieve required behavior and does not involve hazardous behavior, achieves the reduction of product failure on the design stage. A multi-phased interaction design enables the designer to design the complex product system with less system failure from an early design stage.

2.3. Failure Reduction on Production Process Planning Stage

The production process can be represented as the translation process of product quality by a sequence of the operations [5]. Based on the model of the production process, the production failure is modeled as the causal chain between a production process and a product on process. The operation changes a product quality state. The production failure is caused by bad operations, bad operation sequence and bad material. The production failure model represents the whole state change of production process based on a production model.

A planner of production process must design a sequence of operations with less production failure. Based on a production failure model, computational method of planning system that does not involve a production failure is developed. The input of planning system is a required state of product quality, and the output of planning system is a sequence of operation that does not result in the quality problem. Integration between the multi-staged product behavior design and the process planning method provides the designer the product development with less failure.

2.4. Failure Information Database

The model of a product behavior and a production process provides the meta-model of design error and production failure. A failure information database can be developed

based on the meta-model. The failure database enables a designer to share and access on each stage of a product design and a production process planning.

The meta-model based database can be categorized as following four databases: 1) a generalization and specialization database, 2) decomposition and recombination database, 3) causal relationship database and 4) actual data and case database. Those four databases and the stepwise design process enable a designer to reduce a product failure from the early product design stage and the early production planning stage.

2.5. Stepwise Refinement Model

The computational management and representation method of design process is necessary to support the product development from early design stage. In order to represent the design process, the model of the designer's decision process is required. This paper assumes that the design process is the embodiment process of the product (and production process). The embodiment process increases the volume of the product information. Hence, this paper assumes that the increasing information model can represent the product information in the design process. Based on the increasing information model, a seamless design support is realized from the initial design stage to the detailed design stage using same product representation model.

Figure 2 shows the failure reduction concept by stepwise refinement of this research. The information processing procedures can be categorized into two axes: 1) mapping from the design stage to the production stage, and 2) detailing process by the decomposition. The zigzagging design process enables a designer to design a product and a production process with full-time comparison of a requirement by multi-staged approach. That means why this design method can reduce the new difficult product failure systematically.

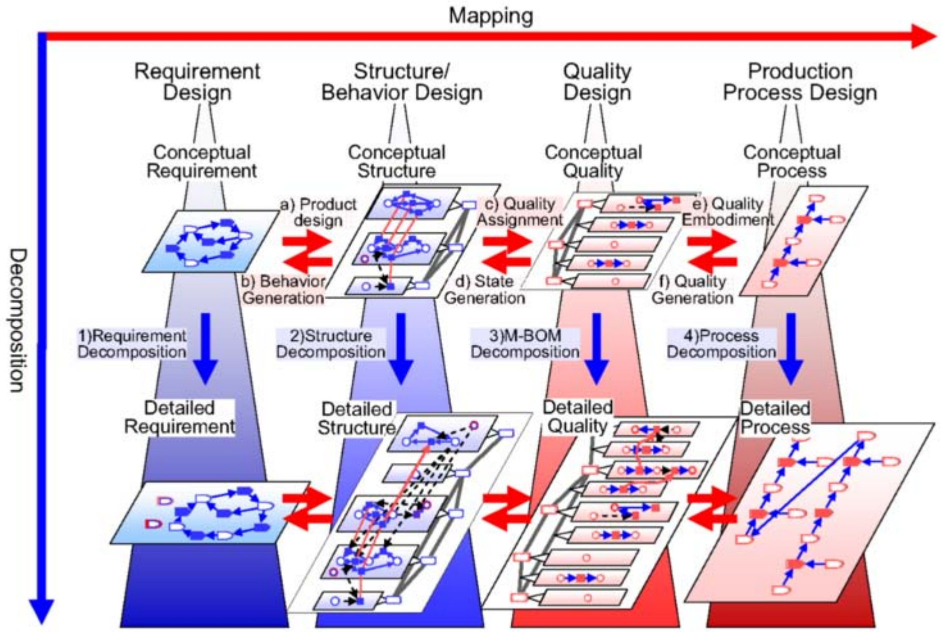

Figure 2. Information Processing Procedures for failure reduction on design and production stage

3. Prototype System

Based on the discussions in the previous sections, the prototype system is developed using pure object oriented language Smalltalk (CINCOM VisualWorks 7.4). Figure 3 shows the overview of the proto-type system. The model view provides the structure of a product behavior model and a production process model. The knowledge view provides the failure knowledge by proposed four databases. The attribute view provides a visual product state in a production process and behavior. The design process view provides the roll-back operation, generating candidates and try & error to avoid a product failure.

The prototype design system can simulate the state change on a product behavior and production process. Based on a production process simulation, the product state is determined. Based on the product behavior simulation, a product failure is calculated. The integrated model and simulation function enables a designer to know the reason of current failure, an impact of process and product change and the better design candidate in the view point of a product failure and its production quality. Hence, this system provides the on-stage check-list and information candidates for PFMEA (Production Failure Modes and Effects Analysis) and FTA (Failure Tree Analysis).

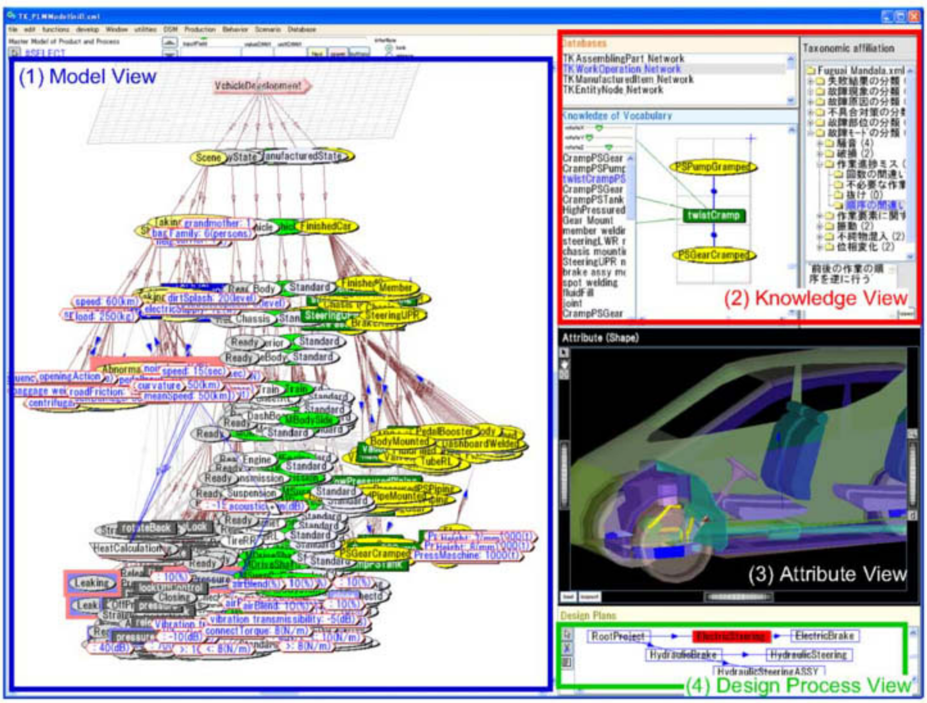

Figure 3. Snapshot of Prototype System

4. Conclusion

The design method of product and production process with sharing failure information is proposed in this paper. The shortening of product development time and reduction of the wasteful design iteration can be reduced based on the detecting and accessing of a quality related issues in a production process that derives critical product behavior. The production model and product behavior model proposed in this paper visualize the process of the product quality and product behavior that satisfies the required behavior.

This visualization will accelerate the communication between product design engineers and production planning engineers. The designer can know what is going on in the production process. The production planning engineer can know why a component is required and how to behave through the entire product life cycle.

In the future, based on the knowledge sharing and process integration by the proposed method, we hope engineers provides unprofessional product failure information with each other, and new technological break-through opportunities will be created by proposed design system.

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Service-driven Web manufacturing: A Roadmap from Methodology to Applications

Pingyou JIANG, Shuishi FUKUDA
Xi'an Jiaotong University, China, Tokyo Metropolitan University, Japan

Abstract. This invited talk deals with studying a service-driven web manufacturing methodology and exploring its potential applications in industry. In the aspect of methodology, basic equipment e-service model, manufacturing executive system configuration, and system running in the context of real-time information scheduling, sharing and tracking mechanism are three key issues that should be solved in advance. On the basis of our bottom-up research strategy, first of all, an e-service fundamental model attached to any a CNC machine tool is put forward. It is actually a server front-end of the machine tool and is able to provide online service functions including machining data sampling and handling, process quality control, machining operations visualization, collaboration, etc, through three modes, that is, access mode, subscription mode and broadcast mode. In terms of connecting all server front-ends with each other, secondly, we establish a web-based manufacturing executive system referring to decomposing the manufacturing tasks and allocating necessary manufacturing resources by means of using both BOM and Gantt charts. Furthermore, this web-based manufacturing executive system in a "Browser/Server/Web Database" three-tire architecture can run under the control of real-time information scheduling, sharing and tracking mechanism based on a time-dependent instantiated template net (TIT-net). As methodology verification, we use an industrial case to demonstrate the methodology mentioned above. The further potential applications in industry are also discussed in detail in this invited talk.

Biographical notes: Pingyu Jiang is a professor at state key laboratory for manufacturing systems engineering at Xi'an Jiatong University, China. He received his PhD in Mechanical Engineering from Xi'an Jiaotong University, China in 1991, and was promoted to a full professor in 1999. He also held Humboldt and JSPS international post doctoral Research Fellowships from 1995 to 1999 in Germany and Japan respectively. In 2003, he got a short-term visiting professorship again from the JSPS. Professor Jiang is the author and co-author of over 60 journal papers, 2 teaching textbooks, and 1 monograph. Since 2003, he has been a member of editorial board for both *International Journal of Manufacturing Technology and Management* and *International Journal of Mass Customization*. His main research interests include e-manufacturing, virtual manufacturing, product design methodologies like product platform design for mass customization and MEMS design.

Dr. Shuichi Fukuda is professor at Tokyo Metropolitan Institute of Technology (TMIT), Japan. He received Doctor's Degree in Mechanical Engineering from University of Tokyo, Japan in 1972. From 1976 to 1991, Dr. Fukuda was an associate professor at Osaka University. He has taken a professor position at TMIT

since 1991. Prof. Fukuda is also active members for several societies like IEEE, ASME, etc. Till now he has published more than 80 journal papers and 30 books.

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Workshop 1: Web Services in CE

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A formal model for Web service composition

Freddy Lécué and Alain Léger{freddy.lecue, alain.leger}@rd.francetelecom.com
France Telecom R&D, France,
4, rue du clos courtel F-35512 Cesson Sévigné

Abstract. Automated composition of Web services or the process of forming new value added Web services is one of the most promising challenges in the semantic Web service research area. Semantics is one of the key elements for such a task. Even if semantics enables Web service to describe their capabilities and processes, there is still some work to be done. Indeed Web services described at functional level need a formal model to perform the automated composition of Web services. The suggested model (i.e. Causal link matrix) is a necessary starting point to apply problem-solving techniques such as regression-based search for Web service composition. The innovative model supports a semantic context in order to find a solution for an AI planning-oriented Web service composition.

Keywords. Semantic Web, Web service, Automated composition and reasoning.

1. Introduction

Web service [1] provides the feature richness, flexibility and scalability needed by enterprises to manage the SOA challenges. By Web services we mean loosely coupled, reusable software components that semantically encapsulate discrete functionality and are distributed and programmatically accessible over standard internet protocols.

Web services proliferation over the web implies difficulties to find specific services that can perform specialized tasks. Nevertheless a combination of existing services is an alternative and promising approach although manual Web service combination from scratch can be difficult and time consuming. That is why new abilities are necessary to support dynamic and automated tasks such as discovery, selection and composition. The main ability is to describe capability (inputs, outputs, preconditions, and effects: IOPEs) and process model (Web services activities, interaction protocol) of Web services. The latter needs are covered by means of semantic Web services. Indeed a semantic Web service [26] is described as a Web service whose internal and external description is in a language that has well-defined semantics. Most of the work in semantic Web services composition has focused on two main levels of composition: functional [20,24,13] and process [6,18,21] levels. The former level considers Web services as "atomic" components described in terms of their IOPEs, and executed in a simple request-response step. The latter level supposes Web services as stateful processes with an interaction protocol involving in different sequential, conditional, and iterative steps. The functional and process level composition as complementary methods is an interesting trade-off to pro-

pose solutions for composition. Hence the study of a formal model for the functional level composition or the process of chaining Web services according to their functional description. The semantic matching of TBox concepts is behind this composition's level.

The rest of the paper is organized as follows. Section 2 introduces a motivating example through an e-healthcare scenario. Section 3 presents the causal link matrix (CLM) as a formal model to describe Web services at functional level. In section 4, an AI planning-oriented method is presented to solve a Web service composition with a specific CLM. We briefly comment on related work in section 5. Finally in section 6, we draw some conclusions and we talk about possible future directions.

2. A motivating example: An e-healthcare scenario

The scenario focuses on a telemedical collaboration for the purpose of reducing additional consultation, examination, medical check up fees for improving patient follow-up. Indeed a complete clinical observation in hospital is no longer a realistic issue for cost reasons, especially for the elderly, hence a long distance follow-up. A solution of the previous problem consists of implementing a composite and value-added Web service that can automate the patient follow-up by a reliable Web service interoperation.

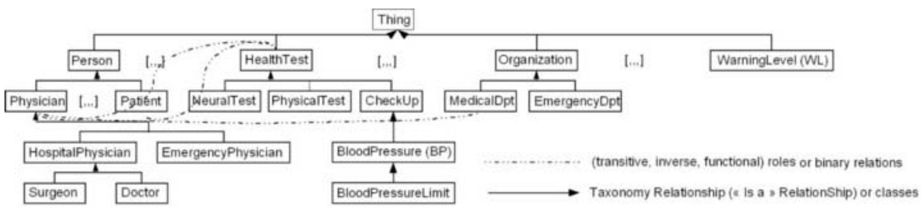

Figure 1. A sample of an e-healthcare ontology $\mathcal{T}$.

Consider the above scenario with six different Web services: S_a returns the blood pressure (BP) of a patient given his PatientID (PID) and DeviceAddress (Add); S_b and$S_{b'}$ return respectively the supervisor (Person) and a physician of an organisation; S_c returns a level of warning (WL) given a blood pressure; S_d returns the Emergency department given a level of Warning; S_e returns the Organization given a level of Warning.

3. Formal model

Algorithms for Web service composition have to not only find feasible plans with relevant Web services, but also to find the optimal plan according to an optimization criteria. The latter criteria will be viewed as a quality of semantic connection between Web services. Indeed the semantic connection between Web services is considered as essential to form new value-added Web services. The formal model (i.e. the Causal link matrix CLM) aims at storing all those connections (i.e. causal links) in order to find the best Web service composition. A causal link describes a semantic relation between an output parameter $Out\_s_y \in \mathcal{T}$ of a Web service s_y and an input parameter $In\_s_x \in \mathcal{T}$ of a Web service s_x. Thereby s_x and s_y are semantically and partially linked according to a matchmaking function $Sim_{\mathcal{T}}(Out\_s_y, In\_s_x)$ with $\mathcal{T}$ a terminology (e.g. Figure 1).

Match Type	*Exact*	*Plug-in*	*Subsume*	*Fail*
$Sim_{\mathcal{T}}(Out\_s_y, In\_s_x)$	1	$\frac{2}{3}$	$\frac{1}{3}$	0
Logic meaning	$Out\_s_y \equiv In\_s_x$	$Out\_s_y \subset In\_s_x$	$Out\_s_y \supset In\_s_x$	Otherwise

Table 1. Semantic matching functions described by $Sim_{\mathcal{T}}$.

The CLM pre-computes all semantic links between Web services as an Output-Input matching because a Web service composition is mainly made up of semantic connections. Thus Web service composition is mainly oriented by the CLM of the domain. The idea behind the CLM is a model for functional level composition of Web services.

3.1. *Semantic web context and Web service composition formalism*

Parameters (i.e. input and output) of Web services are concepts referred to in an ontology $\mathcal{T}$ (e.g. OWL-S profile [2], WSMO capability [11]). Finding a semantic similarity between two parameters Out_s_y and In_s_x is similar to find a mapping [14] between two knowledge representations encoded using the same ontology $\mathcal{T}$. Causal links store this semantic similarity. Despite some methods[19,16,8], solving a mapping problem is hard because the syntactic form of two knowledge representations rarely matches exactly. Four kinds of semantic matching [19] are considered in our model to check semantic similarity between a concept Out_s_y and a concept In_s_x. Semantic similarity is valued by the $Sim_{\mathcal{T}}$ function (Table 1). For example, the *Plug-in match* means that an output parameter of service s_y is subsumed by an input parameter of the succeeding service s_x. The $Sim_{\mathcal{T}}$ function is necessary to value Web services connections.

Web service composition is close to function composition in the mathematical area. A trivial Web service composition of two Web services s_y and s_x is considered as a mathematical composition $s_x \circ s_y$. The latter composition means that s_y precedes s_x and there exists a positive value of $Sim_{\mathcal{T}}$ between all input parameters of s_x and some output parameters of s_y. CLMs (i.e. matrices of semantic connections) are introduced with the aim of finding not only trivial but also more complex composition.

3.2. *Causal link matrices*

CLMs contributes to the automated process of Web service composition by classifying Web services according to a formal link called "causal link". A causal link is related to a logical dependency among input and output parameters of different Web services.

A causal link [22] is refined as a triple $\langle s_y, Sim_{\mathcal{T}}(C_o, C_i), s_x\rangle$ such that s_x and s_y refer to two Web services in a set of available Web services S_{Ws}. The concept C_o is an output parameter of the service s_y whereas the concept C_i is an input parameter of the service s_x. The function $Sim_{\mathcal{T}}$ is the function of semantic similarity described in previous section. $Sim_{\mathcal{T}}$ returns a value in $[0, 1]$ depending on the matching degree between the concepts $C_o,\ C_i \in \mathcal{T}$. A causal link $\langle s_y, Sim_{\mathcal{T}}(C_o, C_i), s_x\rangle$ requires that i) s_y precedes s_x, ii) no Web service is interleaved between s_x and s_y.

Definition 1. *A causal link $\langle s_y, Sim_{\mathcal{T}}(C_o, C_i), s_x\rangle$ is valid iff $Sim_{\mathcal{T}}(C_o, C_i) > 0$.*

Example 1. *According to section 2, $\langle S_d, Sim_{\mathcal{T}}(EmergencyDpt, Organization), S_{b'}\rangle$ is a valid causal links whereas $\langle S_b, Sim_{\mathcal{T}}(Person, Organization), S_{b'}\rangle$ is not.*

i/j index	1	2	3	4	5	6
i.label	Address (Add)	BloodPressure (BP)	Organization	Patient	Warning Level	
j.label	Address (Add)	BloodPressure (BP)	Organization	Patient	Person	Warning Level

Table 2. Labels of the rows and columns of the 5×6 matrix $\mathcal{M}$.

A causal link matrix contains all legal and valid transitions for a composition goal because causal links help to detect inconsistencies. Indeed all valid causal links between Web services are explicitly valued by the $Sim_{\mathcal{T}}$ function. The latter value is based on the semantic quality of valid causal links. The CLM aims at storing all those valid causal link in an appropriate way. The more valid causal links there are, the better it is.

Definition 2. *(Causal link matrix CLM)*
Let $\mathrm{M}_{p,q}(\mathcal{P}((S_{Ws} \cup \mathcal{T}) \times]0,1]))$ be the set of $p \times q$ matrix[1] whose entries are in $\mathcal{P}((S_{Ws} \cup \mathcal{T}) \times]0,1])$. The (i,j) entry of a matrix $\mathcal{M}$ in $\mathrm{M}_{p,q}(\mathcal{P}((S_{Ws} \cup \mathcal{T}) \times]0,1]))$ is denoted by $m_{i,j}$. Rows $\{1,\ldots,p\}$ of a causal link matrix are labelled by inputs parameters of services in S_{Ws}: $Input(S_{Ws})$. Columns $\{1,\ldots,p\}$ are labelled by inputs of services in S_{Ws} and concepts described by the goal set $\beta \subseteq \mathcal{T}$: $Input(S_{Ws}) \cup \beta$.
Each entry $m_{i,j}$ is denoted by a set of pairs $(s_y,\ score) \in (S_{Ws} \cup \mathcal{T}) \times]0,1]$ such that

$$(s_y, score) = \begin{cases} (s_y, Sim_{\mathcal{T}}(C_o,\ C_j)) \subseteq m_{ij}\ if\ s_y \in S_{Ws} \\ (s_y, 1) \subseteq m_{ij} \qquad\qquad\qquad if\ s_y \in \mathcal{T} \end{cases} \tag{1}$$

with $C_o \in Out(s_y)$ and $C_j \in \mathcal{T}$ such that C_j is the label of the j^{th}column.

Suppose that i and j are respectively labelled by the concepts $C_i, C_j \in \mathcal{T}$. Input(S_{Ws})$\subseteq \mathcal{T}$ is the set of input parameters of each service of S_{Ws} whereas $Out(s_y)$ is the set of output parameters of the Web services s_y. β contains the set of goals as concepts in $\mathcal{T}$. The variable $score$ refers to the degree of match $Sim_{\mathcal{T}}(C_o,\ C_j)$ between an output parameter $C_o \in \mathcal{T}$ of s_y and $C_j \in$ Input(S_{Ws})$\cup\beta$ (label of the $j^{th}column$) in case $s_y \in S_{Ws}$. In the alternative case $s_y \in \mathcal{T}$, the value $score$ is 1. A CLM pre-computes the semantic similarities between all output and input parameters of a closed set of Web services. All entries are valid causal links defined in $\mathcal{P}((S_{Ws} \cup \mathcal{T}) \times]0,1])$.

Example 2. *Let $\{S_a, S_b, S_c, S_d, S_e\}$ be the set of Web services S_{Ws} (section 2) and $\{Person\}$ be the goal β. p and q are respectively equal to 5 and 6, thus rows and columns of the CLM $\mathcal{M}$ are respectively indexed by $\{1,...,5\}$ and $\{1,...,6\}$. Labels of indexes of $\mathcal{M}$ are depicted in Table 2. $\mathcal{M} \in M_{5,6}(\mathcal{P}((S_{Ws} \cup \mathcal{T}) \times \{\frac{1}{3}, \frac{2}{3}, 1\}))$.*

According to definition 2, CLMs are defined with p rows and q columns such that $p = \#(Input(S_{Ws}))$ and $q = p + \#(\beta) - \#(\beta \cap\ Input(S_{Ws}))$ hence the CLM dimension [3] $dim_{\mathcal{P}(S_{Ws} \times]0,1])}\mathrm{M}_{p,q}(\mathcal{P}(S_{Ws} \times]0,1])) = p.q$.

Example 3. *The entry $m_{3,4}$ or $m_{Organization,Patient}$ is equal to $\{(S_b, 1)\}$ because a Web service S_b with one input parameter $Organization$ and an output $Person$ semantically similar to $Patient$ exists in S_{Ws}. Indeed $\langle S_b, Sim_{\mathcal{T}}(Person, Patient), S_a\rangle$ is a*

[1] $\mathcal{P}(S)$ refers to the set of parts of S. $\#S$ refers to the Cardinality (or size) of the set S.

valid causal link. The $Person$ and $Patient$ concepts match with the Subsume match *according to the definition of $Sim_{\mathcal{T}}$. The entry $m_{1,3}$ or $m_{Address,Organization}$ is an empty set because there is no Web service S_x (with $Address$ as input in $\mathcal{T}$) and S_y in S_{Ws} such that $\langle S_x, Sim_{\mathcal{T}}(C_o, Organization), S_y\rangle$ is a valid causal link, hence*

$$\mathcal{M} = \begin{pmatrix} \emptyset & \{(S_a,1)\} & \emptyset & \emptyset & \emptyset & \emptyset \\ \emptyset & \emptyset & \emptyset & \emptyset & \emptyset & \{(S_c,1)\} \\ \emptyset & \emptyset & \emptyset & \{(S_b,\frac{1}{3})\} & \{(S_b,1)\} & \emptyset \\ \emptyset & \{(S_a,1)\} & \emptyset & \emptyset & \emptyset & \emptyset \\ \emptyset & \emptyset & \{(S_d,\frac{2}{3}),(S_e,1)\} & \emptyset & \emptyset & \emptyset \end{pmatrix}$$

Suppose $\#(S_{Ws})$, $\#(Output(S_{Ws}))$ and $\#(\beta)$ be respectively the number of Web services in S_{Ws}, the cardinality of output parameters of Web services in S_{Ws} and the cardinality of goals. The algorithmic complexity for the causal link matrix construction is $\theta((Max\{\#(Input(S_{Ws})), \#(Output(S_{Ws}))\}^3)$ so cubic in the worst case [15].

Definition 3. *Let $\mathcal{M}$ be a CLM in $\mathrm{M}_{p,q}(\mathcal{P}((S_{Ws} \cup \mathcal{T})\times]0,1]))$ and $\mathcal{KB}$ be the set of instantiated concepts $\{C_1, \ldots, C_t\}$ such that $\mathcal{KB} \subseteq$ Input(S_{Ws}) $\cap\, \mathcal{T}$. $\mathcal{M}$ is initialised with $\mathcal{KB}$ iff $\quad m_{i,k} \supseteq (C_k, 1)$, $\forall i \in \{1, \ldots, p\}$, $\forall k \in \{1, \ldots, t\}$.*

Example 4. *Let $\{Address, BloodPressure\}$ be the knowledge base $\mathcal{KB}$ and $\mathcal{M}$ be the CLM (example 3). According to the definition 3 and Table 2, the initialised CLM is:*

$$\mathcal{M}_0 = \begin{pmatrix} \{(Add,1)\} & \{(BP,1),(S_a,1)\} & \emptyset & \emptyset & \emptyset & \emptyset \\ \{(Add,1)\} & \{(BP,1)\} & \emptyset & \emptyset & \emptyset & \{(S_c,1)\} \\ \{(Add,1)\} & \{(BP,1)\} & \emptyset & \{(S_b,\frac{1}{3})\} & \{(S_b,1)\} & \emptyset \\ \{(Add,1)\} & \{(BP,1),(S_a,1)\} & \emptyset & \emptyset & \emptyset & \emptyset \\ \{(Add,1)\} & \{(BP,1)\} & \{(S_d,\frac{2}{3}),(S_e,1)\} & \emptyset & \emptyset & \emptyset \end{pmatrix}$$

Property 1. *An entry $m_{i,j}$ from a causal link matrix $\mathcal{M} \in \mathrm{M}_{p,q}(\mathcal{P}((S_{Ws} \cup \mathcal{T})\times]0,1]))$ is different from the empty set iff i) $\exists s \in S_{Ws}$ with at least one input $i.label \in \mathcal{T}$ and one output $C_o \in \mathcal{T}$ such that $Sim_{\mathcal{T}}(C_o, j.label) \neq 0$ or ii) $j.label$ is a concept in $\mathcal{KB}$.*

3.3. Causal link matrix issues

The key contribution of the CLM is a formal model to control a set of Web services which are relevant for a Web service composition. Web services of S_{Ws} are supposed to be relevantly discovered in a discovery process [4,26]. Thus the set of Web services S_{Ws} is closed in order to limit the dimension of the CLM. This model allows performance analysis of proposed plans with a concrete view of the composition background: causal links and their semantic dependency. The CLM aims at pre-chaining Web services according to a semantic similarity based on their Output/Input specification. The CLM is able to prepare a suitable context for an AI planning problem [18] with the purpose of obtaining complete, correct, consistent and optimal plan.

4. AI planning and Causal link matrices

The planning problem is formalized as a triple $\Pi = \langle S_{Ws}, \mathcal{KB}, \beta\rangle$. S_{Ws} refers to a set of possible state transitions, $\mathcal{KB}$ is an *Initial state* and $\beta \subseteq \mathcal{T}$ is an explicit goal repre-

sentation. The Web service composition method consists of finding a plan that produces the desired outputs β according to a knowledge base $\mathcal{KB}$. The causal link score allows the early detection of impossible, feasible and best links between Web services (Definition 1). That is why our method is based on the causal link validity between Web service. Composition as sequences of Web service is a necessary requirement to propose a plan solution. Thus sequence-composability defines a composition $s_x \circ s_y$ if an output of s_y is consumed by an input of another Web service s_x. The sequence-composability knowledge is expressed in CLMs according to Theorem 1 (proof in [15]).

Theorem 1. *Let $\mathcal{M}$ be a CLM, and s_x, s_y be two Web services in S_{Ws}. s_x and s_y are sequence-composable iff $\exists i \in \{1, .., p\}$, $\exists j \in \{1, .., q\}$, $\exists v \in]0, 1]$ such that $(s_y, v) \subseteq m_{i,j}$. $j.label$ and $i.label$ are respectively inputs of s_x $(In(s_x))$ and s_y $(In(s_y))$.*

Example 5. *Suppose the CLM $\mathcal{M}$ in section 3. S_c and S_d are sequence-composable in S_{Ws} if and only if $S_d \circ S_c$ (Theorem 1). Indeed there exists $(i, j) = (2, 6)$ in $\mathcal{M}$ such that$(i.label, j.label) = (BloodPressure, WarningLevel)$. $(S_c, 1) \subseteq m_{i,j}$ with $j.label \in In(S_d) \subseteq \mathcal{T}$ and $i.label \in In(S_c) \subseteq \mathcal{T}$. Therefore the output S_c is consumed by the input of S_d because $Sim_{\mathcal{T}}(Out\_S_c, In\_S_d) \neq 0$ (Table 1).*

4.1. AI planning context and regression-based approach

A simpler form of AI planning is introduced to avoid problems [25] from planning-based Web services composition, e.g. non determinism and implicit goal. The set of Web services S_{Ws} (i.e Actions) is closed by assumption and the *goal* set β refers to a set of concepts in a terminology $\mathcal{T}$. Thus we propose a solution plan in a well-defined domain: goals are explicitly given, initial state is well defined and Web services are strictly defined at functional level. So non determinism, implicit goal, fuzzy Web service description and behaviour are out of the question. Therefore it does seem possible to directly apply current AI planning methods to our specific problem.

The composition process consists of a recursive and regression-based approach. A Web service with a goal β as output parameter has to be found in S_{Ws}. In case of success, the process is iterated with its input parameters as new goals. Alternatively, the process is stopped and the plan is reduced to $\emptyset$. All the process is recursive until all goals and new goals are concepts in $\mathcal{KB}$ (stop condition). The algorithm 1 presents the complete process of composition and returns a plan composed of valid and "*sequence-composable*"causal links. CLMs ease the regression-based search because all Web services are semantically well ordered in a robust and formal model. The solutions are plans wherein Web services are semantically chained by causal links. Instead a regression-based approach, other problem-solving techniques may be applied [12].

Plan constructs are necessary to describe a partial ordering [23] of Web services in Π, hence $\wedge$ the conjunction operator (parallel construct), $\vee$ the disjunction operator (non determinism construct), $\circ$ the sequence construct, and $\wedge > \vee > \circ$ their priority order. The operator $\circ$ defines the sequence-composability between two Web services.

Algorithm 1: Consistent plans set (*Cps*) by regression.

Input: A CLM $\mathcal{M}$ ([$m_{i,j}$]), a plan π, a planning problem $\langle S_{Ws}, \mathcal{KB}, \beta \rangle$, a temporary set of solved goals G, a set of non valid goals β_{nv}.
Result: A set of consistent plans π.
begin
  $S_c \leftarrow \emptyset$; *// Temporary set of couples in* $(S_{Ws} \cup \mathcal{T}) \times]0,1]$.
  if $((\exists C_k \in \mathcal{KB})\ \&\ (Sim_{\mathcal{T}}(C_k, \beta) \neq 0))$ **then** Concat(π, β);
  // Web services discovery with β output.
  foreach $I_i \in Input(S_{Ws})$ **do**
    if $m_{I_i,\beta} \neq \emptyset$ **then**
      if $\exists (\alpha, v) \in m_{I_i,\beta}$ *such that* $(\alpha, v) \notin S_c$ **then** Add($(\alpha, v), S_c$);
  // Plan for Web service composition.
  if $S_c \neq \emptyset$ **then**
    foreach *couple* $(\alpha, v) \in S_c$ *with* $\alpha \in S_{Ws}$ **do**
      $\pi \leftarrow$ Concat(π, $(\bigvee_{S_{ws}} \alpha \circ)$);
      foreach $In(\alpha)$ **do**
        if $\beta \in G$ **then** Concat(π, $\emptyset_\pi$); Add(G, β_{nv});
        else
          Add(β, G);
          $\pi \leftarrow$ Concat(π, $\bigwedge_{In(\alpha)}$*Cps*($\mathcal{M}$,π,$\langle S_{Ws}, \mathcal{KB}, In(\alpha)\rangle$,$G$));
  else Concat(π, $\emptyset$);
  return π;
end

$s_x \circ s_y\ if\ \exists C_o, C_i \in \mathcal{T} | \langle s_y, Sim_{\mathcal{T}}(C_o, C_i), s_x \rangle$ is a valid causal link. The conjunction operator is used to express parallel plans. Such a situation is possible if a Web service contains more than one input parameter (e.g. $m_{1,2}$, $m_{4,2}$). The latter parameters consider new parallel goals in the *Cps* algorithm. The disjunction operator is used if more than one output parameter is consumed by the goal (e.g. $m_{5,3}$).

4.2. Consistency, completeness and correctness properties of solutions

Consistency is a necessary condition for a solution plan. Such a condition is satisfied by plans which contain no cycle in the ordering constraints and no causal link conflicts [22]. The *Cps* algorithm builds such a plan and avoid cycles and conflicts to dispose of inconsistent causal links. The latter inconsistency is tackled by the Algorithm 1 with an update of solved goals. Thus the *Cps* algorithm do not solve goals already solved. The correctness proof of algorithm 1 is detailed in [15].

Example 6. *Let $\mathcal{M}_0$ be the CLM (section 3) and $\Pi = \langle \{S_a, S_b, S_c, S_d, S_e\}, \{Add, BP\}, \{Person\} \rangle$ be the planning-oriented Web service composition problem. We are looking for a "Person" with skills to understand hypertension troubles. The result is a disjunction of six consistent plans: $\pi_{a1} = S_b \circ ((S_d \circ S_c \circ S_a(Add \wedge PID)))$, $\pi_{b1} = S_b \circ ((S_e \circ S_c \circ S_a(Add \wedge PID)))$, $\pi_{a2} = S_b \circ ((S_d \circ S_c(BP)))$, $\pi_{b3} = S_b \circ ((S_e \circ S_c \circ S_a(Add \wedge (S_b \circ \emptyset_\pi))))$, $\pi_{a3} = S_b \circ ((S_d \circ S_c \circ S_a(Add \wedge (S_b \circ \emptyset_\pi))))$, $\pi_{b2} = S_b \circ ((S_e \circ S_c(BP)))$*

Plans suggested by Algorithm 1 do not necessarily satisfy the correctness and completeness properties of plan. Regarding a complete plan [22] as a plan where every input of every Web service is achieved by some other previous Web service, a complete plan is a partial order of well-ordered causal links. By definition, a CLM contains all necessary information about complete plans because a CLM explicitly stores all valid causal links between Web services. Non-complete plans contain empty plan $\emptyset_\pi$ or $\emptyset$ (Algorithm 1) hence open goals. Plans with open goals (e.g. π_{a3}, π_{b3}) are removed from the solutions set because those goals can not be satisfied by $\mathcal{KB}$ or the available Web services.

The plans refinement follows a backward chaining strategy from a goal to initial states. In other words the goal $\beta \in \mathcal{T}$ is recursively produced from a (or some) valid causal link(s) $\langle s_y, Sim_{\mathcal{T}}(C_o, \beta), s_x\rangle$. So correctness of the solution plans is guaranteed by the causal link between the input and output parameters of Web services.

Therefore the algorithm 1 returns a set of correct, complete and consistent plans. However such a set may contain a large number of plans. So pruning strategies for plan-space is necessary to propose a solution. A "causal link"-based optimization criteria is proposed to detect the optimal plan, hence the computation of best causal links in a regression process. The process is recursively executed until the plan is a solution or until the inputs $In(s_y) \subseteq \mathcal{T}$ of the service s_y are concepts in $\mathcal{KB}$. The weight of the optimal plan is computed by means of the CLM and algorithm 1 previously introduced:

$$W_{Max}(\beta) = Max_{S_c}\{\frac{1}{\#In(s_y)^2}\sum_{In(s_y)} m_{I_i,\beta}.score \times (\sum_{In(s_y)}(W_{Max}(I_i)))\} \qquad (2)$$

The recursive function W_{Max} returns the weight of the best plan depending on the goal β. (2) is based on the weight of valid causal links of suggested plans. S_c is a set of couple (s_y, v) such that s_y is a Web service with an output β and input I_i. In other words, $\langle s_y, Sim_{\mathcal{T}}(C_o, \beta), s_x\rangle$ is a valid causal link. The $In(s_y)$ set is the inputs set of $s_y \in S_{Ws}$ whereas I_i is an input of s_y. $\mathcal{M}$ is a CLM with coefficients in $\mathcal{P}((S_{Ws} \cup \mathcal{T})\times]0,1])$. $m_{I_i,\beta}.score$ is the second component of a couple $(s_y, v) \subseteq m_{I_i,\beta}$. Max_S is a n-arity function which returns the maximum value between n float value(s). Given a CLM, the combination of algorithm 1 and (2) is an interesting trade-off to find an optimal (2), consistent (algorithm 1), correct and complete plan when one exists.

Example 7. *The plans π_{a3} and π_{b3} (example 6) are not complete. Weights of plans have been computed with the formula (2).* $Weight(\pi_{a1}) = 1.\frac{2}{3}.1.\frac{1}{2^2}.1 = \frac{1}{12}$, $Weight(\pi_{b1}) = 1.1.1.\frac{1}{2^2}.1 = \frac{1}{4}$. $Weight(\pi_{a2}) = 1.\frac{2}{3}.1 = \frac{2}{3}$. $Weight(\pi_{b2}) = 1.1.1 = 1$.

5. Related work

Two different approaches [7,9] propose matrices to represent the Web services domain. [7] solve an AI planning problem where actions are viewed as tasks. Actions are formally described with their preconditions and effects. Tasks are executed by concrete Web services, according to a service/task (row/column) matrix. [9] propose a simple method to store Web service: an input/output (row/column) matrix. Matrix models used by [7,9] do not propose reasoning about those matrices. In fact, matrices are simply considered as representation models. Moreover no semantic feature is introduced in their models.

From HTNs [27] to regression planning based on extensions of PDDL [10], different planning approaches have been proposed for the composition of Web services. Situation calculus is proposed in [18] to represent Web service and Petri nets for describing the execution behaviours of Web services. A planner is declared as a state chart in [5], and the resulting composite services are executed by replacing the roles in the chart by selected individual services. [17] propose a composition path, which is a sequence of operators that compute data, and connectors that provide data transport between operators. The composition path is based on the shortest path algorithm on the graph of operator space. However, they only considered two kinds of services operator and connector with one input and one output parameter (i.e. the simplest service composition case). [28] propose a forward chaining approach to solve a planning problem. Their composition process terminates when a set of Web services that matches all expected output parameters given the inputs provided by a user is found.

6. Conclusion and future work

Despite the fact that Web service composition is in its infancy, some proposals are being studied. Nevertheless no theoretical model has been proposed to help automation of composition at the best stage of our knowledge. In this paper we outlined the main challenge faced in semantic Web services. Indeed we showed how the CLM tackles this challenge by providing a necessary formal model which draws a concrete context for automatic Web service composition. This concrete context captures semantic connections between Web services. The composition model has its roots in AI planning domain and takes advantage of causal link expressivity by extending its definition in a semantic context. Semantically weighted by $Sim_{\mathcal{T}}$ function, the latter link refers to a local optimization criteria in order to find solution plans. Moreover solution plans have properties of completeness, correctness, consistency and optimality. The model of functional level composition is easily applied to Web services which are described according to OWL-S (service profile) or WSMO (capability model) specification. Finally, contrary to [7,9], our matrix model pre-computes the semantic similarities between Web services (individual inputs and outputs) according to causal links. Web service composition is viewed as causal link composition. For further studies we plan to improve and extend the set of semantic Web service matching functions for optimization reasons. Process level composition of Web services needs to be associated to our functional level composition in order to guarantee a full correctness of the composition process.

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An Automaton-based Approach for Web Service Mediation

Marie-Christine FAUVET and Ali AÏT-BACHIR
University of Grenoble, CLIPS-IMAG
385 rue de la bibliothèque – B.P. 53 – 38041 Grenoble Cedex 9, France
Marie-Christine.Fauvet@imag.fr, Ali.Ait-Bachir@imag.fr

Abstract. Interactions between Web services are based on interfaces which describe Web services on both structural and behavioral perspectives. It can happen that the interface provided by a service does no longer match (for instance, because of an evolution) the interface required by its partners. In this situation, and until the required interfaces are fixed, interactions cannot succeed. To address this issue, and focusing on the behavioral part of interfaces, we propose an approach based on a mediator which aims to seamlessly resolve incompatibilities during service interactions. We adopted a formal tool as finite-state automata, particularly Labeled Transition Systems to model the behavioral aspects of operations exposed by Web services.

Keywords. Web services, conversation, mediation, finite state automata, provided interface, required interface

1. Introduction

Message exchanges form the basics of Web service interactions. Therefore, modeling Web services relies on the descriptions of messages they send and receive and on their interdependencies, as well from the structural point of view (types of exchanged messages) as from the behavioral point of view (control flow between interactions). We distinguish the *provided* interface an existing service exposes, from its *required* interface as it is expected by its clients (which could be softwares of any kind, such as services).

Service interfaces are generally seen as a contract between the provider and its clients. Thus, services are expected to respect their interface. However, a provided interface may need to be modified because, for instance, of an evolution of the corresponding service. When it happens, whether *a priori* for a comparison or *a posteriori* for a compliance test, that the provided interface of a service does not correspond any more to the one its partners expect, two solutions apply: (1) modify the service in order to make the interface it requires match the provided interface; (2) introduce an adapter that reconciles the provided interface with those required by the partners. The former solution is not satisfying because the same service may interact with many other partners which consider its original interface. This leads to the situation where the same service has to expose as many provided interfaces as collaborations it is involved in. The study reported in this text comes within the scope of the latter solution: it consists in providing

an adapter which is capable of matchmaking, at runtime, each of the required interfaces with the one provided by the service.

A service is generally described according to its structural or behavioral dimensions, or even according to its non-functional dimension. Thus, interface matchmaking must be studied according each of these dimensions. Dealing with structural matchmaking essentially leads towards reconciliation between different message types. This issue has been widely studied so far (see for example [14,2,12]) and many commercial systems exist (e.g. Microsoft's BizTalk Mapper). Conversely the problem of behavioral matchmaking is still a research topic [13,16,2,4].

As the development of new services by composition of existing ones has gained considerable momentum as a means of integrating heterogeneous applications and realizing business collaborations, reconciliation of service interfaces is likely to become an hot and crucial topic.

The contributions of the study reported in this paper are mainly:

- An automaton-based model of the behavioral dimension of operations offered by services;
- A mediator which allows clients to keep accessing a service according to the interface they require even after the behavioral interface of the service has been modified.

The rest of the text is structured as follows. In Section 2 we frame the problem addressed and we give an illustrating scenario. Section 3 discusses related work. In section 4 we introduce the automaton-based behavioral interface model and the mediator respectively. Finally, Section 5 concludes and discusses directions for future work.

2. Motivating example

As a working and motivating example we consider a scenario that arises when evolutions of the provided interface of an existing service lead to inconsistent interactions between the service itself and its partners. As stated in the previous section, we focus only on the behavioral dimension of interfaces. The scenario involves two partners: (1) the provider, *Conf* which gives information about scientific conferences (name, important dates, location, organisation and program committees, etc.) and receives from clients papers submitted to a given conference; (2) the client, *Lab* which is meant to be a research group. To keep the example simple we do not model all features expected in a review system (such as for instance paper submission or review process).

The following operations are offered by the service *Conf*:

- *Register(BCN)*: to register by providing a bank card number *BCN*. If the operation succeeded, the returned result is a client identifier, otherwise, an error message is sent back to the client.
- *Login(clientId)*: to log in the service *Conf*. In case of success a session identifier is issued and associated to the client identified by *clientId*, otherwise a error message is returned to the client.
- *ConfList(clientId)*: given a valid *clientId* the operation returns details about forthcoming conferences.

The initial behavior of the operation *ConfList()* is described by an UML sequence diagram depicted in Figure 1(a). Figure 1(b) shows the same operation after its behavior has been changed: now a session has to be open first by submitting *Login()* before *ConfList()*.

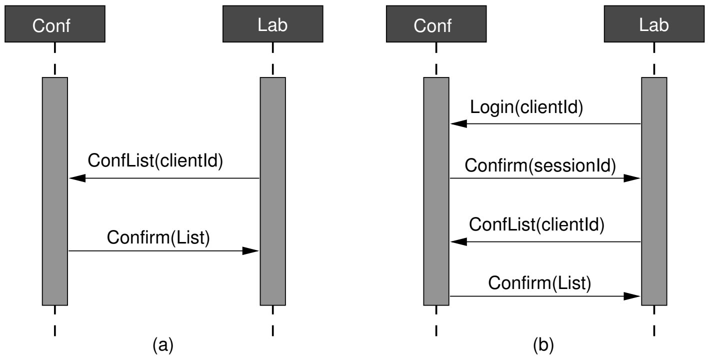

Figure 1. Sequence diagram modeling interactions: (a) initial version, (b) modified version.

The study reported in this article aims at dealing with the issues that arise when clients wish to access a given service, requiring an interface which no longer matches the one provided as operations offered by the service have been changed. Focusing on behavioral point of view of operations, the objective is to seamlessly reconcile interface required by clients with the interface provided by the service, in order to avoid failures.As a first step towards this objective we restrict our focus to interfaces whose behavior is described as a sequence of operations (e.g. operation *Register()* must be executed before operation *Login()*).

3. Related Work

Approaches related to Web service descriptions which focus on behavioral dimension of services are mostly related to standards (see for example WSCI [1,13] and BPEL [16]). In these approaches, the consistency of service interactions rely on collaborations partners have to establish. Specifically, WSCI description does not address the issue related to the matchmaking between service provided interface and those required by its partners. Clients are responsible for using an interface compatible with the one provided by services they wish to access. Other studies propose to translate workflow patterns into a process described in BPEL [16]. In a BPEL process, conversations between partners are orchestrated by the composite service which has the global vision of interactions involved. However, when an evolution of any partner's interface occurs, the compatibility does not hold any more. Then, to fix this incompatibility all partners involved in the composition and concerned by this evolution have to adapt their interfaces.

Web service behavior can be modeled using Petri nets or finite-state automata [9, 7,8,11]. Even though, compatibility checking between two behavioral interfaces can be implemented using bi-similarity algorithms on Petri nets, these approaches do not deal with reconciliation needed when behavioral incompatibilities occur.

In a community-based approach as defined in the SELF-SERV service composition system [6,5], instead of fixing incompatibility of interfaces, the service which provides an incompatible interface is substituted by another taken in the same community. This is satisfying in clients' point of view, but certainly not in providers' point of view: the service whose interface has evolved is no longer accessible via the community, unless an adapter is supplied by the provider.

In dialog theory-based approaches (see for example [3]) paths in a tree model all possible scenarii of a conversation. A path in this tree describes a sequence of actions that lead to a consistent dialog between the client and the service. However, this proposal does not consider interpretation of error messages returned to the client so that it can adapt its behavior. Moreover, each time an evolution of the service occurs all client related to it, must redefine the tree that models the conversation that has been changed.

Mediation has been already proposed to deal with incompatibilities between structural interfaces in service conversations [15,2]. The basics of the mediation, as it was introduced for data integration, is that all messages exchanged between two partners pass through a service mediator also called virtual supplier. The mediator introduced in this paper is based on the same principle, except it is meant to detect and reconcile behavioral incompatibilities. Moreover, the mediator is hosted by the service, not by the client. It is so for many reasons (e.g. security, knowledge of operation behavior, etc.) we can not detail in this paper because of space limitation.

The mediation approach we propose in this text is described and illustrated in the next section.

4. Mediation Approach

We choose to model the behavior of operations provided by a Web service with *Labelled Transition Systems (LTS) [10]*[1]. As an example, the behavior of the operation *ConfList()* is formalised by the LTS shown in Figure 2. Transitions are labelled by events which could be either a message to receive (with prefix $<$), a message to send (with prefix $>$), or a call to an internal operation (with prefix $*$). Intermediate states model execution of internal operations and each final state models whether the operation succeeded or not.

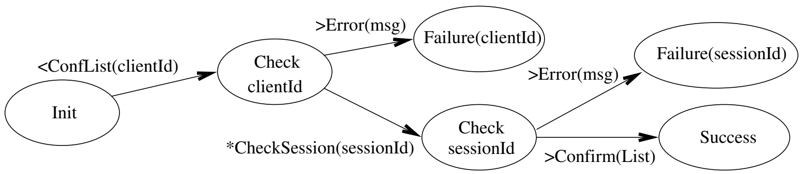

Figure 2. The LTS modeling *ConfList()*.

According to the scenario introduced before, the mediator's role is depicted in the sequence diagram given in Figure 3. Once the message *ConfList()* is received by the mediator, this latter forwards it to the service *Conf* which in turn, checks the validity of the value *clientId* given as parameter and returns an error message because no session

[1]Petri Nets-based modeling was another option. We do not discuss this choice here, as it is out of the scope of this paper.

associated with it has been created before. The mediator then catches the error message and by analysing the LTS associated with *ConfList()*, finds out that the operation *Login()* must be executed first with the value *clientId*. Then acting on the behalf of the client, the mediator submits the login operation *Login(clientId)* to the service. Next, the message requesting the operation *ConfList()* is submitted again, still by the mediator to the service, which this time returns the list of conferences to the client, via the mediator.

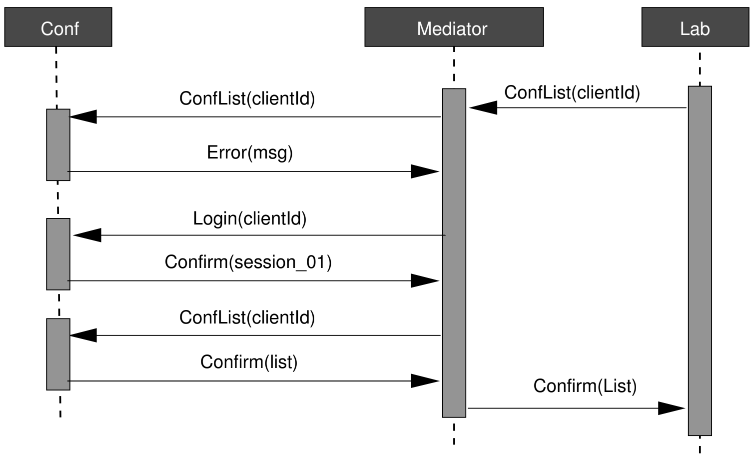

Figure 3. Sequence diagram modeling the reconciliation process

The reconciliation process implemented by the mediator aims to find out the sequence of operations whose execution may fix an error. This process performs the following tasks:

- *Error diagnosis which returns the information which produced the error.* Back to the example (see Figure 2), the automaton ended in a failure state (*Failure(sessionId)*). Starting from this state the algorithm backtracks to the preceding (*Check(sessionId)*) associated with the operation that rose the error. According to the signature of this operation, it is returned that the information responsible for the failure was *sessionId*.
- *Browsing operation LTS which returns the LTSs of missing operations.* This step aims at collecting LTSs of operations whose outputs contain the information that was identified in the previous step. In the example, the LTS to be returned is the one associated with operation *Login()* whose result is either a valid *sessionId* or an error.
- *Composition of returned LTSs and execution.* Eventually, LTSs previously returned are composed with the one of the operation that failed, and then executed. To express the sequential composition of two LTSs, we consider that the successful termination state of the first LTS is the initial state of the LTS which follows it (see Figure 4).

The process above is summarised by the algorithm shown Figure 5: line 5, realises the two first steps, while the lines 6, 7 and 8 do the last one.

The algorithm given in Figure 6, among LTSs of operations offered by the service, seeks those which must be compound in a sequence. The LTS resolving the error is found by trying to match the missing information, in the check state preceding the failure state, with outputs of all the operations of the service (see line 3). The retrieved LTS may have

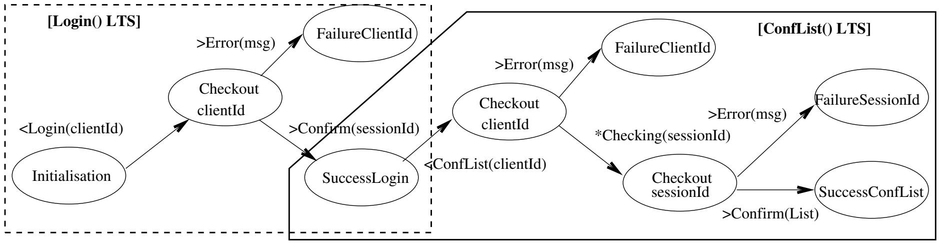

Figure 4. LTSs composition.

```
1  SequenceResolve (Error: Message ; LTSin: LTS )
2      LTSres: LTS                                          { result variable }
3      LTScomponents: List[LTS], Nb: integer           { LTSComponents size }
4      LTSres ← LTSin                      { initialisation with the input variable }
5      <LTScomponents, Nb> ← ListLTS(Error, LTSin)
           { ListLTS(E, L) build a LTS list, with the components number. This list has
           the LTSs to compound }
6      For i← 1 to Nb
7          LTSres ← Compound( LTScomponents[i], LTSres)
8      Process (LTSres)
```

Figure 5. Reconciliation Algorithm

missing information which will generate an error. That is why the algorithm is carried out recursively (see line 7).

```
1  ListLTS (Error: Message ; LTSin: LTS ): List[LTS]
2      ListRes: List[LTS], ListRes←[ ]
3      ListRes←ListRes+LTSop(AllLTS, Error)
           { + denotes the operator that adds an element to a list }
4      LTSin←LTSop(AllLTS, Error)
5      If there are error messages in LTSin
6          Error ← PreviousError(Error, LTSin)
7          ListRes← ListRes+ ListLTS(Error, LTSin)
8      Return(ListRes)
```

Figure 6. Algorithm of method ListLTS.

The algorithm described in Figure 7 shows how two LTSs are compound into a sequence. The initial state of the resulting LTS is the initial state of the first LTS in the sequence (see line 4). The final state of the compound LTS is the final state of the second LTS (see line 5). Finally, the success final state of the first LTS is combined with the initial state of the second LTS (see line 6).

5. Conclusion and Future Work

In this paper, we proposed a mediation-based approach to deal with failures that may arise during interactions between web services. More specifically, we focused on con-

```
Compound (LTSa: LTS ; LTSb: LTS ): LTS
    LTSRes: LTS                                          { result variable }
    InitialState: State, FinalState: State
    InitialState ←SelectInitialState(LTSb)               { to get LTSb's initial state }
    FinalState ←SelectFinalState(LTSa)
                                                         { to get LTSa's final state }
    LTSRes←Combine(LTSa,LTSb,InitialState,FinalState)
        { Combine the two LTSs according to initial and final states }
    Return(LTSRes)
```

Figure 7. Algorithm of method Compound.

versations which cannot successfully complete because client and provider interfaces do not match after changes to provider interface.

We use LTS (*Labelled Transition Systems*) to model the behavior of operations exposed by a service. The mediator provides a technique that searches, among all operations exposed by the service, those whose execution must precede the one which produced the failure. It returns a set of operations, which once composed with the LTS of the faulty operation produces a new LST whose execution reconciles the unsuccessful conversation.

The preliminary work reported in this paper opens several directions. Firstly, we focused on the situation that occurs when a service interface, whose behavior is described by a sequence of operations, is modified by adding new operations in the sequence. This has to be extended by considering any kind of control flow constructs (e.g., loops, conditional routing, switches). Another critical extension is that of considering the case when the algorithm returns many LTSs to be composed. Addressing this issue needs further studies such as defining rules or policies to guide the composition of all returned LTS.

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Workshop 2: Interoperability in CE

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Towards an Ontology-enabled Approach Helping SMEs to Access the Single European Electronic Market

Celson LIMA [a,1], Flavio BONFATTI [b], Silvia SANCHO [c], Anastasiya YURCHYSHYNA [a]
[a] Centre Scientifique et Technique du Bâtiment, BP 209, Sophia Antipolis, France
[b] University of Modena and Reggio Emilia, Via Vignolese 905, 41100 Modena, Italy
[c] AITEX, C/Telers, 20, Ontinyent, Valencia, 46870, Spain

Abstract. The SEAMLESS project targets the design and deployment of a self-organising, open, dynamic collaborative e-environment providing companies (especially SMEs) with the required means to support their e-business needs without cultural/technological constraints. SEAMLESS represents the instantiation of the Single European Electronic Market (SEEM) concept considering the environmental conditions (technical and business-related) required to support simple but useful e-business practices targeting the enlarged Europe. The SEAMLESS conceptual approach is ontology-enabled since the business interoperation heavily depends on how effectively SMEs are able to understand precisely the meaning of the business requests among them. This paper discusses the SEAMLESS vision and framework, and points out the challenges to be faced.

Keywords. E-business for SMEs, ontology, collaborative environment

Introduction

The SEAMLESS project intends to design, implement and assess an advanced ICT-based infrastructure enabling SMEs: (i) to access the eBusiness space created by the Single European Electronic Market (SEEM) here considering the enlarged Europe; and (ii) to play an active role in establishing and running frictionless dynamic collaborations.

The *SEEM vision*, which was explored in the SEEMseed project[2], focus a web-based structured marketplace where companies can easily work together without geographical and technological constraints. SEEM allows an objective comparison of profiles and offers from *SEEM nodes*[3], which should open the eBusiness space to the many small companies (providing high quality products and services at lower cost) that are risking to be left aside from the electronic market.

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[1] Corresponding Author: Celson LIMA, CSTB, Route des Lucioles, BP 209, 06904 Sophia Antipolis, France, Email: c.lima@cstb.fr.
[2] More information at http://www.seemseed.net/.
[3] A SEEM node is a company working actively in the SEEM environment.

SEAMLESS helps to transform the SEEM dream into reality since it aims at defining a collaboration framework and proper business models to catalyse the deployment of the SEEM concept in the enlarged Europe. Additionally, it targets the development the appropriate technological infrastructure together with the necessary applications/services on top of it, showing all the potential and benefits brought by this concept.

SEAMLESS is focused on Craft & Trade companies[4], which are SMEs. Most of them become members of associations (sectoral, regional) that help them carrying out elementary organisational and bureaucratic activities. In other cases the intended companies find the required support on the market, buying services from ASPs (Application Service Providers), or even at local development agencies, chambers of commerce, technology transfer centres and universities. All these are referred to as *Mediators* in SEAMLESS.

The ambition of the SEAMLESS project is to create the organisational and technological conditions to enable mediators, from different countries and sectors, to become nodes of the SEEM network and provide their associated companies with the services needed to access this network and collaborate with other companies.

The paper is structured as follows. Section 1 presents the context of work to be considered by SEAMLESS. Section 1 describes the SEAMLES approach. Section 3 discusses the role of Ontologies in SEAMLESS in relation to interoperability. Section 4 discusses the methodologies and result expected from SEAMLESS. Finally, section 5 draws some conclusions and highlights the challenges concerning the development of the project.

1. The Context of work in SEAMLESS

1.1. The SEAMLESS Operational Scenario

We start with a storyboard of what SEEMLESS aims to provide to SMEs. Through it the project goals and expected results are illustrated and how the project will advance beyond the present state-of-the-art.

The focus is Little Ltd, an SME company that is a member of the Small Association (along with many other SMEs like themselves).

- One day in 2008, Little Ltd is invited by Small Association (SA) to join the SEEM they manage and to become for the first time a participant in the SA electronic market. Little Ltd accepts and receives a URL, a user code and a password.
- Through the URL Little Ltd accesses the Small Association site, is recognised as newcomer and guided in the representation of its features. It means coding and storing in SA's company registry/repository details of its profile, skills and experiences, preferred collaboration forms and contractual templates, as well as its offer (and even demand) of products and services. To this purpose it supported by the local ontology providing lexicon and concepts to associate the right metadata to the stored data. The work is done in the company (and association) home language.

[4] According to ebusiness-watch.org.

– Few hours later Little Ltd receives an unexpected bid request for quotation for the supply of a specific product from Foreign Co, a potential new customer established in a different country. The request is issued according to one of the forms proposed by Small Ltd and made available in its home language.
– The same application suggests to Little Ltd the list of possible reactions it can take (accept, ask for more info, reject, negotiate, etc.). Little Ltd suspends the answer because the requested product calls for the collaboration of partners able to perform special activities that Little Ltd cannot cover.
– Little Ltd plans the required activities, indicates as additional resources its usual partners and fixes scheduling conditions and constraints. On the basis of the scheduler outcome, Little Ltd uses the system to automatically send the relative requests for quotation to the scheduled partners, including Partner Ltd for a certain activity.
– Little Ltd decides that it is time to search for a new partnership in alternative to Partner Ltd. Then it sends to the Small Association site a request for candidate partners meeting a specific profile (region, company size, desired activity, supply time, etc.). the request is broadcasted to the interesting SEEM nodes.
– Within the fixed deadline Little Ltd receives indications of three candidate partners discovered by the system in the respective registries. One of them, New Ltd, is particularly interesting and Little Ltd starts negotiating with it until a quotation has been obtained.
– Little Ltd takes its time to compare the two quotations coming from Partner Ltd and New Ltd. The day after it decides and concludes the negotiation with the selected company (while the system automatically closes the negotiation with the other).
– Now all the data needed to answer the Foreign Co request are available. Little Ltd reacts accordingly and the negotiation continues up to the electronic signature of the contract. On this basis, also the contract with the scheduled partners is finally signed.
– Following these contracts, a number of info and document exchanges take place during the following weeks, according to the specific collaboration protocols. Little Ltd is involved, on the one side, in the envisaged collaborative work with the selected partners and, on the other side, in communications with the customer Foreign Co. Both these relations are regulated and supported by the SEAMLESS workflow manager.

Although simplistic, the storyboard incorporates a number of very real problems that are not solved at the present time and that constitute the ultimate aim of SEAMLESS. They range from easy and fast introduction into the system to guided company self-qualification, up to increased visibility at potential partners and customers, and support in negotiation and collaboration with the identified partners.

1.2. The Targeted Companies

As previously stated, SEAMLESS is focused on Craft & Trade companies. They account for more than 90% of all the European enterprises and for more than 60% of employees. Thanks to their number, diffusion and flexibility they represent a pillar of the European economy and society, and the existence of the European electronic

market itself is subject to their massive participation as credible actors. Because of their limited resources, Craft & Trade companies have serious problems to be completely autonomous in an increasingly complex world and, due to that, they rely on mediators to help them carrying out elementary organisational and bureaucratic activities.

The situation in New Member States and Associated Candidate Countries, where the percentage of Craft & Trade companies is even larger than in EU-15, is generally worse although significant differences are found among countries. Not only the above figures are lower, but there are still problems in the constitution of steady and strong local markets and in establishing fruitful relations with enterprises from other regions and from EU-15 countries.

The support assured by *mediators* is fundamental to introduce small companies into the SEEM world. The SEAMLESS solution intends to be simple, direct, easy to use and cheap. In the SEAMLESS framework, mediators are the only actors that can correctly interpret the company needs, deploy the new solution, and help adapting it to the expectations of every single company. Moreover, mediators can ensure the rapid introduction of a critical mass of companies, to make the SEEM network operate on a large scale.

SEAMLESS success relies on four elements (i.e. collaboration framework, knowledge and languages, technological infrastructure and user-oriented applications), to pursue the operational objectives abovementioned. Once the expected results are achieved and properly combined, they are to be assessed through the embryo of the SEEM network.

1.3. The SEEM Concept and the SEAMLESS Vision

The SEEM concept is *an e-business space where companies can do business with no technological restraints*. Such a concept is less about technology and more about identifying those critical eBusiness processes which find obstacles. Technology must be used properly as an enabler for information flow as required [1].

The purpose of SEEM is to ensure the possibility of integrated value chains, where companies, organisations and individuals from different Member States can be linked in a chain without experiencing any access or interoperability problems[5]. The *SEEM vision* is towards an Internet-based structured marketplace where companies can collaborate without geographical and technological restraints, thus overcoming the limits of the hundreds of vertical portals each adopting its own specific model. It implies, among other things:

- Creating a self-organising network of eRegistries/Repositories (RRs) where companies can classify their own profiles, offers and features so as to gain public visibility to potential customers and partners;
- Providing advanced, semantically-based search & find services to discover candidate partners by selecting them from the RRs on the basis of their profiles, qualification and offer;
- Establishing the conditions for confident and secure dynamic relations, negotiations and information exchanges with other companies based on agreed collaboration protocols and reciprocal trust;

[5] http://europa.eu.int/information_society/activities/atwork/seem_at_work/introduction/index_en.htm

- Offering compliant web applications to manage general-purpose and sector-specific distributed processes, and hide the SEEM infrastructure complexity under easy and tailored user interfaces; and
- Ensuring the interoperability of legacy systems by facilitated information exchanges, to integrate internal enterprise processes (active and passive cycles) with external collaborations.

The instantiation of SEEM depends on the creation of a collaborative environment where SMEs and mediators would come together and interoperate using e-business practices and mechanisms. The SEEMseed project was the first step towards the implementation of the SEEM concept. It worked at the conceptual level, identifying requirements, challenges, technologies available, and also proposing a kind of 'conceptual framework' required to support SEEM. SEAMLESS is the next step. The SEAMLESS project intends to provide this environment (here referred to as SEAMLESS Collaborative Environment) and validate it through a series of pilot cases, involving two industrial sectors (construction and textile).

For the sake of clarity from now on SEEM network and SEAMLESS Collaborative Environment (Figure 1) are going to be used seamlessly, meaning the e-environment where companies are interoperating following the SEEM rules. Another *convention* adopted here concerns the terms SEAMLESS Infrastructure and SEAMLESS solutions, both used to refer to the software application to be delivered by the project.

1.4. SEAMLESS Framework and Business Needs

The SEAMLESS framework (Figure 2) is formed by three main parts, namely the collaborative environment itself, the mediators, and the SMEs associated to each mediator. Essentially, the SEAMLESS collaborative environment is the virtual space where SMEs will make e-business operations through the mediators. Each mediator acts as a kind of *facilitator* between its members and the collaborative environment.

Each interaction is considered a business operation that requires, indeed, a perfect understanding between the actors involved and which is supported by a very particular information flow. Each SME has to be sure about the precise meaning of every single business interaction, not only at the operational level but above all, at the semantic level. SEAMLESS considers that this need can be fulfilled if SMEs share common ontologies managed by the mediators. More details on this are given in section 3.3.

In SEAMLESS, business needs will come from two industrial sectors, namely Textile and Construction. They will be used on order to assess and validate the benefits provided by the SEAMLESS solution. Although different, Textile and Construction are considered complementary to SEAMLESS purposes, including similar business needs, some textile material used in Construction, etc..

2. The SEAMLESS Approach

The SEAMLESS approach is based on four main pillars, namely collaboration framework, technological infrastructure, knowledge and languages, and application and services.

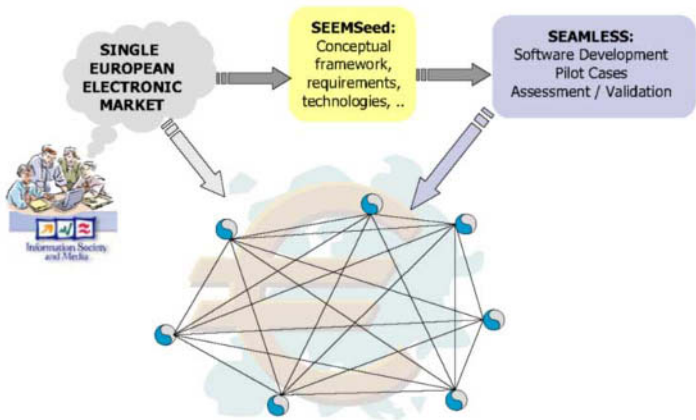

Figure 1. Towards the implementation of the SEEM concept

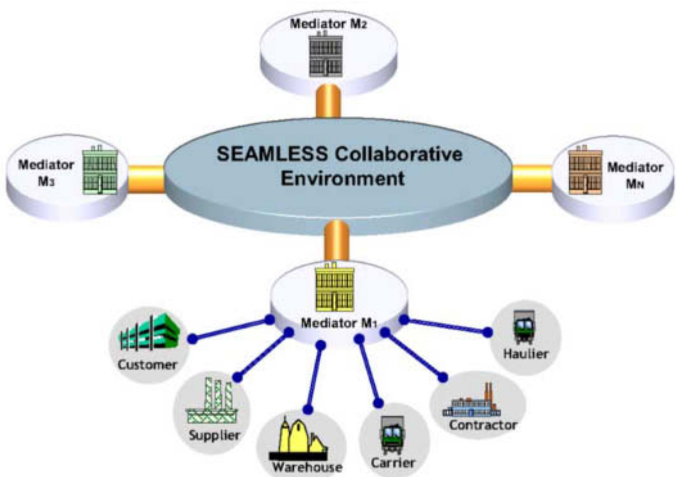

Figure 2. The SEAMLESS framework

2.1. Collaboration Framework

SEAMLESS will develop a collaboration framework taking into account the peculiarities of Craft & Trade companies. Additionally, a corpus of rules, collaboration protocols and templates is to be generated together with proposals for new suited business models.

The collaboration framework is related to the concepts of community process, distributed business model and flexible (dynamic) collaboration between SMEs and with larger firms. The expected innovations introduced by SEAMLESS here are the following: *provide clear and simple negotiation and collaboration rules*, *networking via mediators*, and *warrant with respect to trust and security*.

The work to perform in this domain can be schematised into the following points: *analysis of collaboration habits and needs*, *trusted operational scenarios*, and *new organisation and business models*.

2.2. Technological Infrastructure

From the technological viewpoint, SEAMLESS aims at developing an Internet-based platform enabling mediators of any type to manage SEEM nodes. The technological platform is intended to ensure the required support to access, register, communicate, collaborate, and exchange information according to a peer-to-peer model.

The SEAMLESS technological infrastructure (Figure 3) constitutes the basement assuring secure and technology-independent collaboration and interoperation between user-oriented services. This architecture is derived from the architecture developed by the SEEMseed European project [2]. It is made of two main parts, namely the SEEM general infrastructure on the one side, including Service layer, Core Registry layer and Repository layer, and the Application layer on the other side.

The Service layer is seen by the Application layer through the functions it offers in form of web services to completely decouple the applications from the data storage and management. It must be independent of any specific business framework specification, but has to provide the services needed by them in order to work. It is in charge of managing the local ontology and keeping it aligned with the common (central) ontology. It decides to which RRs data and queries shall be addressed by establishing peer-to-peer connections with them.

The Core Registry layer takes care of distributing data and accessing them in the underlying repositories. It acts as an access point to them and offers an indexing function to find stored information, which can be located in different repositories.

The Repository layer stores and manages the knowledge to be exchanged (both data and metadata), and ensures secure access control and information privacy. It concerns, for instance, company data, technical profile, product or service information, business processes, business documents, contractual agreements.

The Application layer is a set of software functions, hiding the complexity of the architecture, by which the user operates in the SEEM. According to the SEAMLESS approach, the applications take great advantage of the knowledge and the functions made available by the SEEM Service layer on top of which they are built. Some examples of applications likely to be integrated as part of the SEAMLESS solution are: Intelligent search engine for business interoperation purposes, applications supporting business negotiation and collaboration, and applications supporting the integration of legacy systems into the SEAMLESS world.

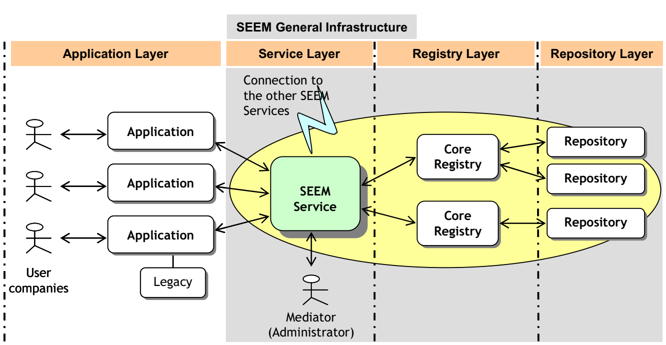

Figure 3. Technological perspective in SEAMLESS

2.3. Knowledge and Languages

The SEAMLESS framework is supported by three ontological levels (Figure 4). In the first one, the Global Level, there is a Global Ontology handling the semantic needs of the whole collaborative environment. In the second one, the Mediator Level, mediators are expected to be supported by Common Ontologies handling the semantic needs of each mediator. In the third one, SMEs are supported by their Local Ontologies, which are mapped into the respective common ontology. A common ontology has to support the semantic mappings required to allow each SME to be able to operate, throughout its respective mediator, into the SEAMLESS collaborative environment.

SEAMLESS is considering the possibility to define a global ontology according to the Global-as-View (GAV) approach, and then map the meta knowledge classified in every Registry/Repository (the local ontology) onto the global ontology. Also, the common ontology is expressed in English as *lingua franca*, while the common/local ontologies are expressed in the respective languages.

The implementation of a *multi-lingual support* in a situation where there will be at least five working languages, in addition to English as lingua franca, is very critical. This last innovation is particularly important considering the ultimate project aim of strengthening the collaboration between companies in the Enlarged Europe.

The knowledge made available by a registered company in the respective Registry/Repository is, in general, not easy to understand as it is because of cultural and linguistic differences with the searching entities. The problem is overcome by associating meta-knowledge to explain the meaning of the stored data, and organising this meta knowledge into a consistent lexicon and ontology.

Broadly speaking, the main concepts initially considered to be represented into SEAMLESS are the following:

- *Company/profile*: general concepts describing a company in terms of name and other identifying properties, legal status and type, size (turnover, employees), markets, and so on;
- *Industry and product/service classification*: the taxonomy representing the type(s) of industry and the type(s) of products/services that can be used to characterise the activities carried out by the company;

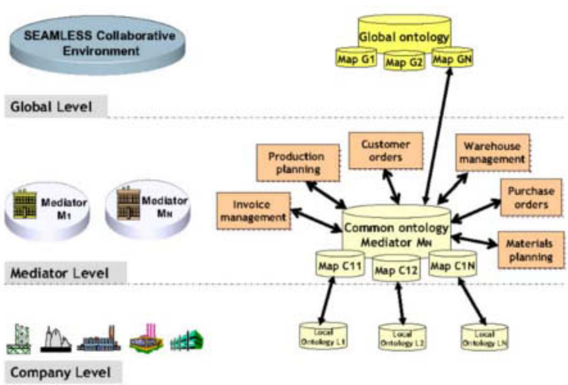

Figure 4. Ontological layers in SEAMLESS

- *Geopolitical location*: the taxonomy representing the geographic location of the company, its plants and its customers and markets; and
- *Business information*: concepts needed to express the data to exchange while making business with a partner, such as request for quotation, bid, orders, etc..

The SEAMLESS approach, although conditioned by the limitations of the target companies, can also take advantage of the facilitation role of mediators, such as:

- *Easy and limited ontologies*: the target companies use small vocabularies, and the related concepts constitute small ontologies. In the SEAMLESS project there is no need, nor resources, to define rich and complex semantics.
- *Strong support form mediators*: mediators can play a critical role in defining sectoral/regional ontologies, by extracting them from the daily practices and from the lexicons used by the member companies.

SEAMLESS will support the mediators to create their common ontologies. Additionally, mediators will be provided with a suited *mechanism to propagate changes* from their common ontology towards the global ontology as well as to other common ontologies. Ontology alignment/mapping and propagation function in such a working environment is another innovation introduced by the SEAMLESS project.

2.4. Applications and Services

They represent the functions provided user interface that, definitely, hide and exploit the complexity of the underlying infrastructure.

As a matter of fact, without integrated services and applications, SEEM is empty and the technological infrastructure is practically useless. For the SEAMLESS purposes, the identified applications are those more interesting for the target small companies, namely partner search, support to negotiation, support to collaboration, and interoperation of legacy systems. Their implementations on top of the technological infrastructure represent an actual innovation for the following reasons:

- *Solutions for SMEs*: first challenge is to provide SMEs with applications that are easy to use and cheap enough to be affordable even with limited resources;
- *New SEEM-compliant solutions*: some of the foreseen applications are conceived to exploit at best the knowledge and functionality managed by the technological infrastructure. They are new solutions that must rely on right analysis of requirements and be potentially replicated in different contexts.
- *Wrapping existing solutions*: other applications will be developed by adapting and wrapping existing solutions so as to make them become compliant with the SEEM structure without loosing the familiarity that users have already appreciated of them.

3. Ontologies in SEAMLESS

3.1. Ontology-related Requirements

In SEAMLESS, ontological needs come from the need to support business interoperability involving actors having different profiles among them, which includes

business practices, languages, etc.. The three-layer based approach previously explained aims to handle all semantic-related needs found in the SEAMLESS operational scenario. The SEAMLESS Collaborative Environment must be accessible, in a *seamless* way, to all organisations aiming at taking part of the SEEM.

It is worth noticing that there is a need to combine the ontology-related requirements from the two industrial sectors present in SEAMLESS. The first point to analyse is how the global and local ontologies will be created and mapped onto each other, having however in mind the preference of the centric GAV approach. With respect to the proposals coming from the literature, in the SEAMLESS project there is a completely new aspect to consider, that is, the need to adapt theoretical solutions to a real-life working environment.

On the other side, a simplification explicitly introduced by the project is limiting the ontology construction to only two sectors, that is, to their terms and concepts. The second point to consider is how to manage the changes that will be introduced into the local ontologies, to cope with new information and application needs, and how to propagate them to the common ontology (and transitively to the other local ontologies).

The orientation is towards a disciplined update of the common ontology, which is preferred to version management for its simplicity and ease of implementation, and the automatic communication of changes to the interested nodes. Once again, the problem consists in selecting the most promising techniques from the literature and adapting them to a complex working environment. Once studied and defined the solutions for ontology management and multilingual support, the next critical step is realising the common ontology.

3.2. Ontologies in Construction

SEAMLESS will take advantage of previous works carried out at European level tackling semantic-related needs in Construction. They are, in particular, the e-COGNOS [3] and eConstruct [4] projects, both addressing the development of taxonomies/ontologies for Construction, while the FUNSIEC project is focused on ontology mapping [5].

Other reference sources are the sector standards such as LexiCon vocabulary, an implementation of the ISO DIS 12006-3 standard, the British Standard 6100 produced by the British Standard Institution, and the UNICLASS construction information classification system that covers information generated from all phases of a construction project.

In performing this work, special care will be put actual user preferences, since the experience showed that very specific, concise and precise taxonomies are normally preferred to big ontologies [6]. Then, the creation of the ontology for Construction will likely follow a simplification process starting from the large available vocabularies (several thousand terms) to a limited but validated set of concepts (several hundred).

For illustrative purposes only, the implementation of a truly European e-procurement service (for the Construction sector) must take into account the Construction regulations and norms of the countries making business. This cannot be handled in a case-by-case basis; rather only a solid (but completely invisible to the SMEs) ontology-enabled mechanism can guarantee that.

3.3. Ontologies in Textile

In the textile sector the starting point is constituted by the rich taxonomy already created by AITEX, together with the contribution found at other international and national projects and the analysis of standards in the sector. We can recall here BUSCATEX [7], an advanced tool for self-classification of products and services by the industrial companies in textile & clothing. Another reference is the technical analysis done by AITEX, in 2004, about the state of the art of the eBusiness standards and their applicability to the textile sector. Other experiences are the SMADETEX[6] and SEWNEW[7] projects, both contribute in the multilingualism issues and develop a common terminology related to defects and textile processes. Even in this case the ultimate objective is to obtain a lexicon which is, at the same time, limited in size and covering the actual annotation and communication needs of users.

4. Methodology and Expected Results

Broadly speaking, the SEAMLESS methodology is based on several phases, starting with the characterisation of each sector in terms of business needs, collaboration processes, products, overlapping areas, and so on. Another phase will cover knowledge and language related requirements, where ontologies and classification systems currently used in both sectors are to be analysed as potential candidates to help overcoming semantic problems found in SEAMLESS. On the technology side, results produced by DBE project (namely the *DBE Studio* – editor of Business Process – and the *Exe Execution Environment*) are to be analysed as potential candidates to become part of the SEAMLESS infrastructure. Alternatives are the AXIS 2 or the STIL technology. Finally, application and services are to be identified based on definition of the SEAMLESS usage scenarios for Construction and Textile.

Some of the results expected in SEAMLESS are the following:

- SEAMLESS infrastructure ready to use: represents the implementation and operation of a SEEM-related infrastructure realising the specifications (and going beyond the demonstrator) of the SEEM concept;
- *Ontology creation, mapping and evolution*: analyse how global, common and local ontologies will be created and mapped onto each other. In SEAMLESS there is a real need to adapt theoretical solutions to a real working environment. Other aspect to consider is how to manage the changes that will be introduced into the local ontologies, to cope with new information and application needs, and how to propagate them to the common ontology (and transitively to the other ontologies). The orientation is towards a disciplined update of the common ontology, which is preferred to version management for its simplicity and ease of implementation, and the automatic communication of changes to the interested nodes;
- *Support to collaboration in a multilingual environment*: a simple but effective support allowing every company to keep using its native language, and the

[6] Please see www.aitex.es/frames/proyectos_IDI/europeos/Smadetex/smadetex.htm for more information.

[7] Please see www.sewnews.com for more information.

other companies reading the same information in their respective native languages. The SEAMLESS solution must exploit the local and global ontologies and their mappings in such a way to minimise the effort (for the mediator holding the single SEEM node) to initialise and periodically update lexicon and concepts;

5. Challenges and Conclusions

There are very interesting challenges expected to be found in the development of SEAMLESS, ranging from: (i) *incomplete understanding of company needs and requirements*, passing throughout the (ii) *legal constraints that can be an obstacle to the full deployment of the single electronic market*, till the (iii) *resistance to the adoption of the proposed collaboration environment and software infrastructure*.

SEAMLESS is fully aware that the road is not going to be an ease one and every challenge will be properly tackled. For instance, (i) can be avoided since SEAMLESS is developed in steps, including activities to assess progress and results to draw indications for problem recovery. In turn, (ii) although not dealing directly with legal problems, the project aims at overcoming the risk by involving policy makers at the regional, national and European levels, and using for them the pilots as living examples and, as such, preventing having problem (ii). And finally, (iii) can be avoided with a wide representation of mediators in the project, and the specific attention to study new business models should provide hints to facilitate SEAMLESS solution.

SEAMLESS represents an instantiation of the SEEM concept. As such, it targets the deployment of pilot cases setting up the embryo of the SEEM network, where the SEEM nodes are, essentially, Craft & Trade companies. Two industrial sectors are to provide the business needs and scenarios where the SEAMLESS infrastructure is to be deployed, assessed and validated. SEAMLESS has just started, i.e., there is still 24 months of work ahead us and the framework is defined, vision is created, preliminary methodology is being executed, targets are settled, beats are on the table. SEAMLESS will be producing its first seeds in the next months.

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Enabling Adoption of STEP Standards Through the Use of Popular Technologies

Carlos AGOSTINHO[a,1], Marco DELGADO[a],
Adolfo STEIGER-GARÇÃO[b], and Ricardo JARDIM-GONÇALVES[b]
[a]UNINOVA, Portugal
[b]DEE, FCT-UNL, Portugal

Abstract. With the advent of globalization, enterprises, especially Small and Medium Enterprises (SMEs), need to be efficient, effective and to embrace innovation. These characteristics are vital in order to face the global market environment, which raises the need for collaboration and interoperability in a more demanding and competitive industrial scenario. Interoperability and standardization are proven approaches to leverage collaboration and help establishing business networks, increasing competitiveness of organizations. However, some of these organizations have been experiencing some problems when trying to adopt one of the most important standards for the exchange of product data, the STEP (ISO10303). These problems are due to the poor software support and usage of complex technologies. This paper proposes as a solution, a framework for the harmonization of STEP conceptual models and knowledge with other standard technologies commonly adopted by today's organizations. The results presented in this paper has been supported and validated in the scope of the some European/International industrial research projects like the IMS SMART-fm (www.smart-fm.funstep.org), Athena-IP (www.athena-ip.org), and InterOp (www.interop-noe.org).

Keywords. Conceptual models, harmonization, Interoperability, STEP, Model Morphisms

Introduction

To achieve competitiveness in today's global environment, companies need to engage in more sophisticated business networks and improve collaboration. However, establishing these business networks is an ongoing challenge companies are facing, due to the diversity and heterogeneity of systems, software applications and technologies used by the participants. For instance, with so many different modeling and implementation languages being used in systems development, interoperability problems can arise when the chosen product model is described using particular technologies different from the ones the system is required to be integrated with [1],[2],[3].

A proven approach to deal with the heterogeneity of systems is to enforce interoperability, leveraging the adoption of data standards and enabling the integration

[1] Corresponding Author: Carlos AGOSTINHO, UNINOVA – Instituto de Desenvolvimento de Novas Tecnologias, Campus da FCT/UNL, Monte de Caparica, 2829-516 Caparica, PORTUGAL; E-mail: ca@uninova.pt

of systems across organizations. Interoperability and standardization activities are playing an important role in lowering costs and prices, and increasing competitiveness of organizations. To help attain enterprise and the desired systems interoperability, several dedicated reference models covering many industrial areas and related application activities, from design phase to production and commercialization, have been developed [2].

ISO10303 [4], most commonly known as the Standard for the Exchange of Product Model Data (STEP), is one of the most important standards for representation of product information. STEP has developed more than forty standard Application Protocols (APs) for product data representation, reflecting the consolidated expertise of major industrial worldwide specialists working together for more than twenty years. These standards cover the principal product data management areas for the main industries, which provide STEP a distinct advantage over similar technologies and standards [3],[5].

However, the conceptual model information contained by many of STEP neutral standards is often represented using languages that are unfamiliar to most application developers, which difficult its usage and acceptance by many companies [2],[3],[6].

Indeed, organizations are much liable to use more user-friendly technologies and standards, such as Extensible Markup Language (XML), Unified Modeling Language (UML) [2], relational databases standards (RDB), and more recently knowledge representation systems based on Web Ontology Language (OWL) [3] or Resource Description Framework (RDF)[4]. Due to their simplicity and availability of supporting tools, these technologies are popular among application developers and have a huge impact in real world applications [2].

Therefore, in order to facilitate the use of STEP and promote its adoption, the solution would be to develop a standard-base platform that will integrate STEP with these more popular standards and technologies. This will allow reusing its existing expertise and extending its capabilities in complementary application domains, like advanced modeling tools, knowledge management and the emergent semantic web technologies.

This paper presents a framework based on open-standards for the reuse harmonization of STEP conceptual models with other standard technologies more popular among today's organizations. The framework results from the research developed by the authors during the last years, and its testing and validation is has been performed under the scope of international projects.

1. STEP Standard

STEP is a multi-part open-standard for the computer-interpretable representation of product information and for the exchange of product data under the manufacturing domain. The objective of STEP is to provide a means of describing product data throughout the life cycle of a product that is independent from any particular computer system. The nature of this description makes it suitable not only for neutral file

[2] OMG - Unified Modeling Language (2005): http://www.uml.org/
[3] W3C - Ontology Web Language (2005): http://www.w3.org/2004/OWL/
[4] W3C - Resource Description Framework (2005): http://www.w3.org/RDF/

exchange, but also as a basis for implementing product databases and retrieving data [4] ,[7].

STEP Application protocols (APs) are information models that capture the semantics of a specific industrial requirement and provide standardized structures, within which, data values can be understood by a computer implementation. As noted earlier, STEP contains more the forty APs. These are described using ISO10303-11 (Part 11), which represents STEP's modeling language, commonly known as EXPRESS [8].

STEP data has traditionally been exchanged using ISO10303-21 (Part 21) [9], an ASCII character–based syntax. Although it's sufficient for task, it lacks extensibility, it's hard for humans to read, and it's interpretable only by systems supporting STEP. This is one of the drawbacks STEP faces regarding its use and adoption by a wider community. Another drawback is the fact that the STEP modeling language, EXPRESS, is unfamiliar to most applications developer. Although it is a powerful language, it has been relatively unknown in the world of generic software modeling tools and software engineers [10]. As opposed to other modeling technologies, such as UML, few software systems support EXPRESS capturing, modeling, and visualizing its constructs and relationships.

In summary, the STEP standard, despite being very powerful regarding the representation and the exchange of product data, is not very popular among the application developer's community.

Therefore, and because of the massive adoption and deployment of other standard technologies, like XML and UML, the authors believe that the path to follow is to harmonize these standard technologies, leveraging the cemented knowledge gathered by STEP, with the popularity of the other standards. This harmonization among complementary technologies would become a powerful force for lowering the barriers to widespread exchange and share of digital data.

However, these standards and the STEP reference models where developed using dissimilar methodologies and described using different languages. Indeed, there was no global plan for them to be interoperable with each other. To subsequently achieve interoperability, it is necessary to develop additional methodologies to support their integration [11].

2. Common used Technologies and Standards

Many kinds of information standards exist that cope with different needs like product data modeling, electronic business documents, information exchange, etc. In the context of this work, the authors identified some of the most important standards that can leverage STEP's usage and adoption.

2.1. Product Modeling Standards

2.1.1. XML Schemas (XSD[5])

XSD is the XML modeling language, broadly used on definition of technology architectures and structures, over the internet and on internet based application

[5] W3C - XML Schema (2005): http://www.w3.org/XML/Schema

systems. As an open-standard, XML forms the basis of application integration, especially over internet. It has quickly become the language of choice for e-business interoperability. XML is simultaneously human and machine readable. This feature makes it very valuable because, by providing a way for a wide range of data to be exchanged directly by computer systems in a human readable format, it dramatically lowers the cost of development.

In addition, XML is easily extensible and is supported by numerous software tools. Many applications developed today that import or export data, use or support some form of XML format.

In order to take advantage of XML massive adoption and flexibility, ISO has developed a standard for representing EXPRESS schemas and instances population in XML, namely ISO10303-28 (Part 28). Part 28, not only allows developers to use low-cost, ubiquitous XML software tools to implement file-base exchange and visualization of STEP instances, but can also permit the use of STEP information in XML-based Web Services environments [6].

2.1.2. Unified Modeling Language

UML is very acquainted by application developers, and has become "de facto standard" for software engineering. It's a language for specifying, visualizing, constructing, and documenting the artifacts of software systems, as well as for business modeling and other non-software systems. The UML represents a collection of the best engineering practices that have proven successful in the modeling of large and complex systems. Compared to STEP, UML related tools abound, which facilitates the task of many organizations that want to use it [10].

In contrast with UML, the tools that are used to develop and manage STEP schemas and instantiate populations have a relatively small user community. Many modelers and implementers do not understand STEP when they have to deal with instances. It's difficult to understand relationships among STEP's constructs and other kind of information that were used in their development process. UML provide mechanisms, like class diagrams, that can facilitate the modeling process.

As with XML, ISO10303-25 (Part 25), is an ISO standard which defines the rules for mapping EXPRESS schemas to UML models. Part 25 enables developers to use their familiar UML tools to see the contents of STEP (EXPRESS) schemas and eventually to specify relationships between STEP information models and the other UML models that they use [6].

2.1.3. W3C Semantic Web Standards

The Semantic Web is an emerging field, with the aim of extending the current Web infrastructure in a way that the information is given a well defined meaning, enabling software agents and people to work in cooperation by sharing knowledge [12].

However, semantic contents are not only restricted to the Semantic Web. EXPRESS information models also contain rules and constraints that applications can use to test data sets for correctness through conformance checking mechanisms. These prevent the propagation of incorrect data from one application to another. The emerging Semantic Web technologies, like OWL and RDF, have been bringing new possibilities for the exploitation of STEP Application Protocols at knowledge level and in the Web [3].

2.1.4. Relational Database Standards

Databases has become a central organizing framework for many information systems, taking advantage of the concept of data independence, which allows data sharing among diverse applications. Relational database management systems (RDBMS), today incorporate high-level programming facilities that do not require one to specify in detail how the data should be processed. Besides this, RDBMS are very powerful for massive data storing and retrieving, thus being adequate to be used in parallel with STEP.

Through STEP Part 22, specifications for SDAI (Step Data Access Interface), it is possible to access to a STEP-based database from user-developed applications [13].

Moreover, STEP has more mechanisms that allow working in conjunction with databases. As mentioned earlier, EXPRESS information models contain rules and constraints that applications can use to test data sets for correctness through conformance checking mechanisms. These prevent the propagation of incorrect data from one application to another. Every object in the database is examined to determine whether it complies with the rules and constraints defined in the application protocol EXPRESS model [14].

2.2. Information Exchange Standards

One of the principal foundations for interoperability is to enable the exchange of information between ICT systems in an efficient ant automatic way.

As mentioned before, STEP data (i.e., an instance population of an EXPRESS schema) is traditionally exchanged using ISO10303-21 (also known as Part 21 of STEP). ISO10303-28 (Part 28) has become more popular in the last years due to the use of XML instead of ASCII based files. But STEP also has other neutral exchange formats. For example, the mark-up language part of PDML is another attempt to define a schema neutral early-bound representation of EXPRESS data, with a focus on capturing as many of the schema constraints in the XML document type rules as possible [15].

Other widespread information exchange standards are Electronic Data Interchange (EDI), and the W3C Simple Object Access Protocol (SOAP[6]) [10]. XMI (XML Metadata Interchange)[7] is another neutral format, described in xml, used for the exchange of UML models

Other extensions to XML have been made in the area of electronic exchange to replace traditional EDI by ebXML standards and schemas to support electronic business transactions [10].

3. Technologies for Visualization and Information Browsing

Graphical visualization and browsing of data are also very important, especially during development stages were an easy view and understanding of the full scope of the model is needed. Visual representation facilitates the understanding of the reference model, and the abstraction levels that a visual object may represent, brings a suitable and

[6] W3C - Simple Object Access Protocol (2003): http://www.w3.org/TR/soap/
[7] OMG - XML Meta Data Interchange (2005):
http://www.omg.org/technology/documents/formal/xmi.htm

attractive mechanism to understand, navigate and manage the contents of the model [16].

For example, graphical XML editors present very interesting features regarding the navigation of XML documents that some times can be very extensive and complex to analyze. The grid layout exhibited in XML tools (e.g. XMLSpy[8]) allow users to focus in the structure of particular elements isolated from the rest of the document content, facilitating the browsing of the information.

However, for complex structures, other visualization technologies (e.g. hyperbolic tree representation and graph representation) exist and are more suited for information browsing.

The hyperbolic tree representation, as in Figure 1, gives a tree-like hierarchical structure visualization of the information, and provides the possibility to have represented levels of abstraction with expand/collapse functionalities. A graph-based representation, like in Figure 2, is slightly different because does not impose any kind of restrictions on the relationships between the nodes.

A different perspective of visualization approaches resides on the product data visualization systems, like geometrical representation of product (i.e. CAD), which are principal targets of interoperability frameworks. In the last 25 years, designers have created numerous 3D artefacts with vast potential for reuse. Most products have in their later stages of PLC to be visualized using CAD systems, thus needing to be interoperable with different conceptual models technologies as the ones mentioned in the previous section. The Universal 3D (U3D[9]) and X3D[10] are examples of alternative efforts that intend to simplify the transformation of complex 3D data into a neutral non-proprietary format [10].

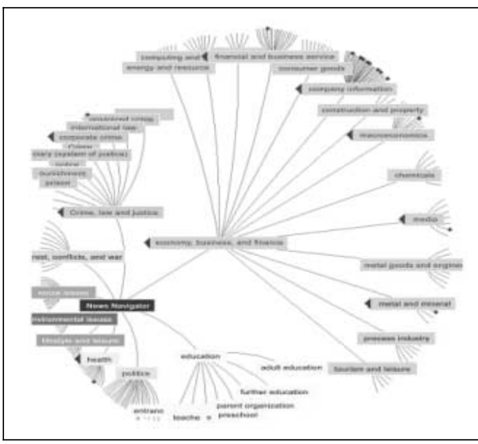

Figure 1. Hyperbolic tree representation

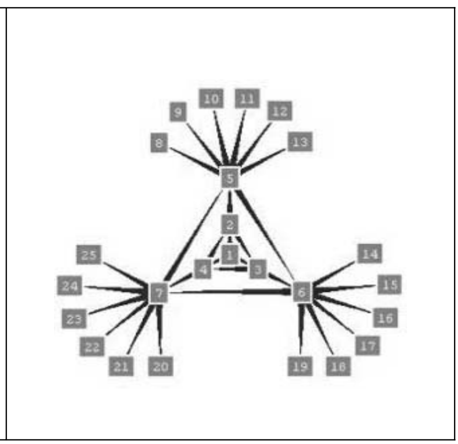

Figure 2. Graph-based representation

[8] Altova – XMLSpy (2006): http://www.altova.com/
[9] 3DIF – Universal 3D (2005): http://www.3dif.org/
[10] Web3D - XML-enabled 3D (2005): http://www.web3d.org/x3d/

4. Framework for the Transformation of STEP Models

The authors propose a framework (Figure 3) for the harmonization of STEP conceptual models with more popular technologies. It allows the transformation of STEP AP models, originally described using the EXPRESS modeling language, into some of the different technologies presented in the previous section.

The methodology followed to achieve the desired harmonization, comprises four different phases which correspond to layers of the framework: input, instantiation, transformation and output.

In the input layer the STEP model is parsed using an EXPRESS parser. This parser was developed based on the ExParser developed at the National Institute for Standardization and Technology (NIST)[11].

The information extracted from the model in the input phase, is used in the instantiation layer to instantiate an EXPRESS meta-model. This meta-model consists on an object-oriented representation of EXPRESS, which was created based on the language specification. The meta-model was first described in XML schema (XSD) format and than transposed to object oriented, using a XML Data binding tool, namely the Castor XML framework[12].

This task was required, in order to achieve one of the primary goals of the framework's implementation, which is extensibility. This way, one can easily develop other modules according to specific needs and plug them into the framework's transformation layer, as long as their implementations follow specific rules.

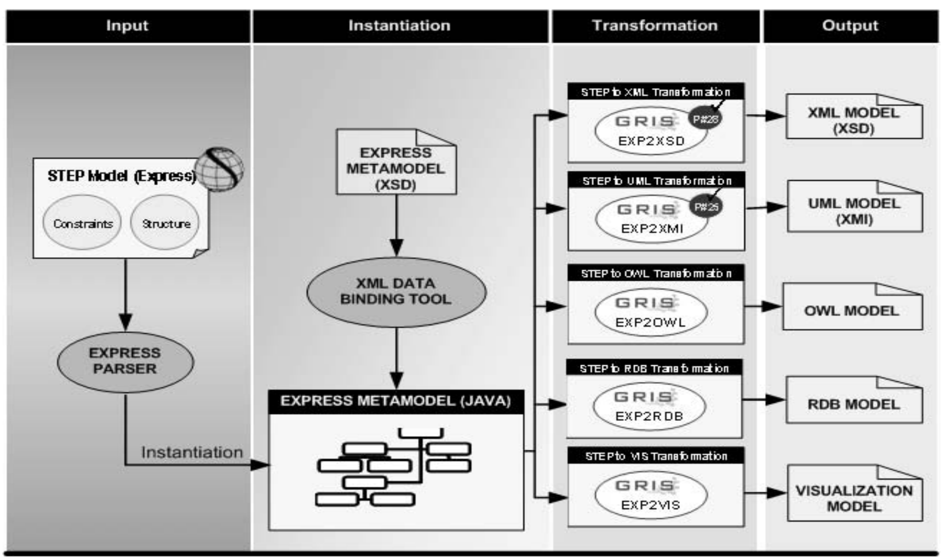

Figure 3. STEP-based harmonization framework

[11] NIST: http://www.nist.gov/
[12] The Castor Project: http://castor.codehaus.org/

Having the meta-model defined and instantiated in object-oriented, becomes possible to establish a set of mapping rules to be used by the transformation layer, enabling the automatic generation of any desired output.

In the transformation phase several translation tools, one for each desired target language, take the instance of the meta-model and transforms it according to specific mapping rules (Figure 4). The translation can follow standard rules, as in the case of XMI and XSD translators, but that is not mandatory.

The translations are based on the concept of Model Morphisms, which addresses the problem of mapping and transformation of models. There are two classes of morphisms: non-altering morphisms and model altering morphisms. In non-altering, given two models, source and target model, a mapping is created relating each element of the source with a correspondent element in the target, leaving the two models intact. In model altering morphisms, the source model is transformed using some kind of transformation function that applies a set of mapping rules to the input model, modifying it into the targeted output [17].

The framework follows the second methodology, as it presupposes that the mapping rules are already defined.

Currently the framework contains the following translators:

- **EXP2XSD** - Translates an EXPRESS schema into XML Schema format, according to the mapping rules defined by Part 28 of STEP.
- **EXP2XMI** - Translates an EXPRESS schema into XMI format, according to the mapping rules defined by Part 25 of STEP.
- **EXP2OWL** - Translates an EXPRESS schema into OWL format. The standard rules for performing this translation are currently under development.
- **EXP2RDB** - Translates an EXPRESS schema into SQL schema format.
- **EXP2VIS** - Translates an EXPRESS schema into a visualization tool compliant format.

Finally, in the output layer, the desired output model is obtained and can be used by any organization or system which required for it.

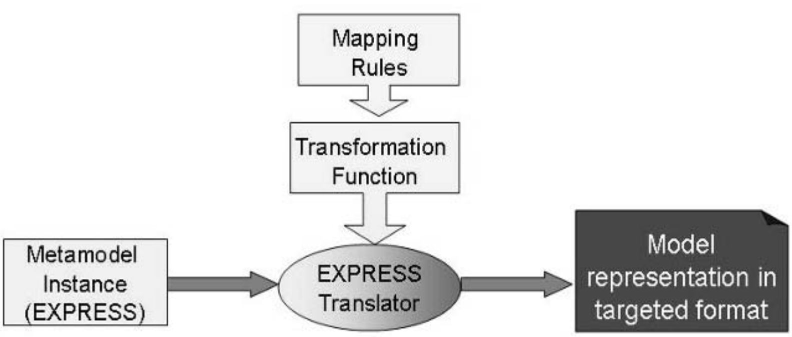

Figure 4. Common architecture for the translators (model altering Model Morphism)

```
SCHEMA Organization_type_arm;

ENTITY Organization;
  id : OPTIONAL STRING;
  name : STRING;
END_ENTITY;

ENTITY Organization_organization_type_relationship;
  organization : Organization;
  organization_type : Organization_type;
END_ENTITY;

ENTITY Organization_type;
  name : STRING;
  description : OPTIONAL STRING;
END_ENTITY;

END_SCHEMA;
```

Example 1. EXPRESS schema

A simple example is presented to illustrate the results of applying the proposed methodology to a given EXPRESS schema (Example 1), and transforming it to obtain the correspondent UML model (Figure 5).

The schema specifies an ISO application module [4],[16] for representation of the data that identifies a type of an organization (e.g. sales, marketing, manufacturing, etc.). The UML class diagram was automatically generated after importing the correspondent XMI output file, produced by the framework, into an UML modeling tool, namely StarUML[13].

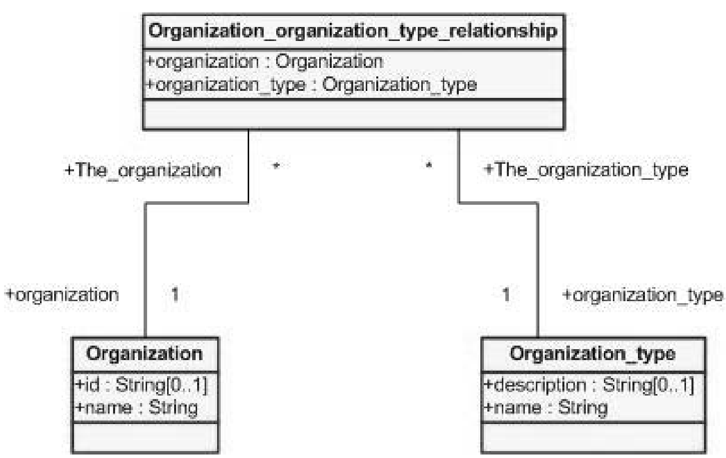

Figure 5. UML class diagram of example 1

[13] StarUML: http://www.staruml.com/

5. Conclusions and Future Work

Information and communications technology combined with the use of open-standards can be a very powerful tool to improve enterprise competitiveness. Companies have been searching for flexible integrated environments to better manage their services and product life cycle, where their software applications could be easily integrated independently of the platform in use. However, with so many different modeling and implementation standards being used, interoperability problems arises when the chosen product model is described using one particular technology (e.g. EXPRESS) and is required to be integrated with systems that use totally different technologies such as semantic-based systems (e.g. OWL). Being ISO10303 STEP acknowledged, by most of the major industrial companies in the world within different sectors, as one of the most important family of standards for exchange of product data under the manufacturing domain, it would be expected to be broadly used. However, that is not so, especially on SME-based environments because the technology is unfamiliar to most application developers.

This paper proposes a framework for the transformation of STEP conceptual models to support data model integration and interoperability at meta-level. Through its usage, the expertise available in the many standard APs can be reused using more popular technologies, and the integration between legacy systems, applications and services could be eased, thus stimulating collaboration between businesses.

The results presented in this work has been applied and validated in several European/International industrial research projects (IMS SMART-fm [18], Athena-IP [19], and InterOp[20])

The authors are considering the evolution of the framework in order to extend its functionalities and cope with other dimensions like Process Modeling and Conformance Testing.

6. Acknowledgments

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IOS Press, 2006

Interoperability issues in CONNIE *Creating a network of decentralised portals*

Tomo CEROVSEK [a,1], Celson LIMA [b], Gudni GUDNASON [c], Graham STORER [d], Marco PADULA [e], and Marcelo BLASCO [f]
[a] Faculty of Civil and Geodetic Engineering, University of Ljubljana, Slovenia
[b] Centre Scientifique et Technique du Bâtiment, BP 209, Sophia Antipolis, France
[c] Building Research Institute, Reykjavik, Iceland Iceland
[d] Storer Consulting, United Kingdom
[e] Istituto per le Tecnologie della Costruzione, CNR, Italy
[f] The Belgian Building Research Institute, Brussels, Belgium

Abstract. Peer to peer decentralized hybrid networks are well established but are most frequently used to connect desktop machines for fun services. We present a concept that enables creation of p2p like networks where nodes are information portals enabling eBusiness activities. The paper gives an overview of such network and interoperability issues.

Keywords. Interoperablity, decentralized portals, network,sso, eBusiness

Introduction

One of the most important barriers to enter cross-border EU construction market are Building Regulations, which do have a crucial impact on the quality of the built environment. The importance of building regulations is illustrated with well known facts about the construction business environment: it employs around 20% of EU workforce, it consists of 97% of SME companies and most of the activities are project-oriented. Although EU building regulations are being harmonized, provisions can be conflicting, hard to track, and are error prone. Gray [1] explains "Buildings are bigger, more complex, and contain more people than ever before. They are therefore more expensive and prone to bigger failures and greater loss than ever before. Society depends on their continued functionality and financial stability. The main three goals of CONNIE are: (1) to extract, organise and index building regulations and normative documents and related contents addressing AEC specific information needs, (2) to promote the deployment of an European Network where the Regulation/Standard-related contents are shared and exploited from a business perspective, (3) to design and implement the software infrastructure to support the abovementioned network[2].

[1] Corresponding Author: Tomo CEROVSEK, Faculty of Civil and Geodetic Engineering, University of Ljubljana, Slovenia, Email: Tomo.Cerovsek@fgg.uni-lj.si.

1. User requirements analysis

User needs are defined by the type of: (1) tasks - carrying out specific tasks with specific information needs, professional roles, (2) context - in which users will interact with the system, and (3) content - available to the end users in a specific context.

Context is firstly defined with the construction business environment – as described in the introduction – was later assessed in more detail in relation to the use of information relevant to the development of CONNIE. An important factor defining the context is the technology environment that was analysed in surveys like [3]. The following IT factors are important for the CONNIE system: access to the internet in AEC, benefits of IT in the sector, Use of internet, and encouragement for IT, and trends in digital exchange.

Content is described through internationally recognized classifications of legislative and normative documents (i.e. Uniclass, and International Classification of Standards). Content was analyzed according to six major parameters: (1) Ownership and Access, where conventional copyright plays major problem; (2) Format – XML should play a more important role in the future; (3) Structure; (4) Metadata; (5) Volume, which is growing exponentially; and (6) Dynamic nature of building regulations.

Actors were analyzed and divided into seven categories: (1) Legislative powers; (2) Standardizing bodies,; (3) Building Construction Entities; (4) Support entities; (5) Resource suppliers; (6) Institutional entities; and (7) Educational entities. Through a detailed analysis of actors' roles, key needs are presented with corresponding activities related to building standards and regulations. In general, actors are divided into two main groups - producers and consumers with sometimes conflicting interests. Based on surveys, we define user needs that do not follow some common patterns and often use social networks. We describe the systems envisaged through user stories.

1.1. Business process modeling

As a representative case study we illustrate regulations' life cycle of the ISO [4] organization that has one of the most well established and effective procedures for the development of standards. The procedure is illustrated with following IDEF0 diagram presented in Figure 1.

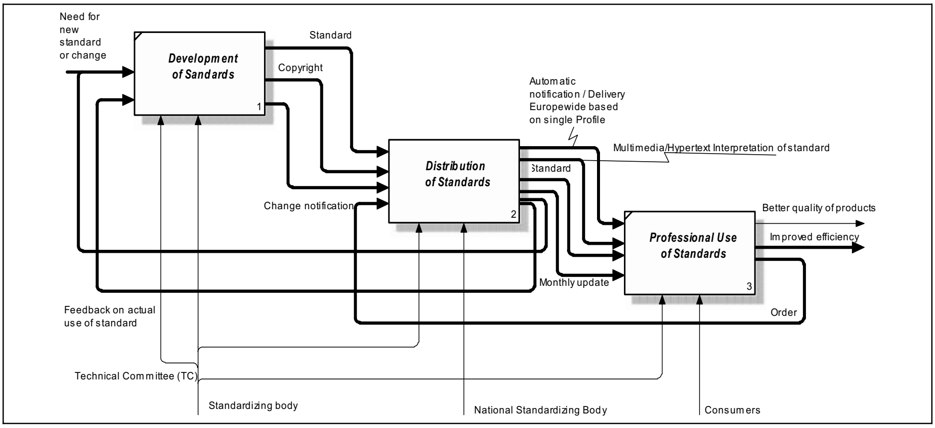

Figure 1. IDEF0 TO-BE model of CONNIE effects on the use of standards

The process of the development of standards is crucial for the success of a standard, especially in an international environment. The process starts with identified need, and goes through various changes to become an international standard. The influence of the CONNIE system to the distribution and use of regulations is presented with bold arrows represent affect ICOMs (i.e. feedback, identification of needs, notification). Consequently, there is an evident improvement of all three major activities in the life-cycle of standards: development, distribution as well as professional use of standards. The CONNIE story board illustrates the advantages.

1.2. The CONNIE story board

For illustrative purposes only, the following absolutely non-technical storyboard shows most of the features expected to be provided by the CONNIE solution. It is worth mentioning that this is the very first global scenario. Some refinements are expected taking into account the evolution of the work as well as the specificities from each country having a CONNIE service provider.

Prologue:

Let me introduce myself. I am a French Building Services Engineer mainly specialising in Heating & Ventilation systems. I work for an engineering practice on many different types and sizes of project. We often provide sub-contract design services to a large French building contractor usually for projects in France but sometimes for projects that their subsidiaries in other countries are undertaking. I was trained in French standards and regulations, and in recent years European standards, but I also need to understand regulations in other countries when dealing with certain sectors like health. Along with other designers of all disciplines these days, my principal tool is the computer – for design, communication and for information search. In my work I must take into account diverse legal, normative and informative documents that are distributed in different formats, representations and locations on the web.

Let me tell you something about today's task. Over the next couple of days I have been asked to give preliminary advice on Heating &Ventilation for the operating theatres in a proposed new hospital to be built in UK. I did a similar assignment two years ago for a French laboratory complex, but I have no knowledge of the differences for a hospital in UK too!

So now you know a little about me and the project I need guidance on. **What I need first is information on the French regulations concerning hospitals over and above the general building codes I am familiar with**. Having that should inform me on the important factors I need to concentrate on – and in **my own language too**! But I also need the current general UK building regulations and the regulatory guidance documents that might exist for their hospitals. So you have **my personal profile**, **my project profile** and the **profile of the kind of information I need**. Of course the profiles are a little more detailed than these, but they illustrate enough, I think. If I were to put into Google my search parameters they might read "UK FRENCH BUILDING REGULATIONS HOSPITAL HEATING VENTILATION". The trouble is that I would get thousands of references and potential pointers but no focused help on obtaining quickly the right information - fine if I am doing academic research but not much use if I am up against a tight deadline and need sound information from reliable sources.

CONNIE So, **today I want to introduce you to CONNIE**. She is a pretty good assistant to me in my task and she never tires! CONNIE is an enquiry system that networks Europe, linking many of the key information providers for the construction sector. It does more than just link information providers; **CONNIE provides a service that searches its "national nodes" seamlessly without me having to log in and out of different providers**. Because the **French node knows me** (by my profile!) other nodes accept me and allow their information to be searched on my behalf. This idea is not unique to construction, of course, and is known as **single-sign-on** (SSO – and a real answer in an emergency). The **business arrangements**

have been sorted out between the different providers so as to reflect their contributions. I am simply given one itemized bill each month depending on the information I have downloaded. Of course, CONNIE gives me a profile of the information it has found before I buy it so that I determine what I want to take and at what cost. **Some information is bundled into my annual subscription to the French node, but I pay for the rest by use**. It's easy!

My CONNIE Session

Let me log-in to CONNIE. I happen to be sitting in my car because I have only just left the project meeting but can access the Internet and CONNIE's web services conveniently. I want to get some of the basic information I outlined above and pass it to my colleague to browse through ready to discuss with me first thing tomorrow morning. **CONNIE will parcel up what I download and forward it under password to authorised persons that I designate**. This is just one of many services CONNIE provides – **although this is particular to France and one or two other countries as an added-value service and is not a universal part of CONNIE**.

Once **connected to the French portal** (in fact there is more than one access provider in France and competition therefore!), I enter my identity and password. If necessary I can amend my personal profile either permanently or temporarily in order that CONNIE can filter and order information retrieved in the way most relevant to me. Optionally, I can put in a **profile of the project I am working** on so that CONNIE can better focus results (ignoring information on housing, say, because I want information on industrial buildings and hospitals in particular). I decide to enter outline details of the new project (including the likely start date so that I can be advised on any regulations that are soon to change – i.e. to know of draft as well as operative regulations).

On-line I can enter the profile of the information I want. The approach to specifying the profile is common across CONNIE nodes, but the way it appears (and perhaps one or two clever search features!) is unique to each node. Basically, I enter the fields of interest (document type(s), technical area(s), project type etc). I also specify UK and France as countries of interest (the latter is default, of course) and hit the SEARCH button and off CONNIE goes.

CONNIE responds very quickly – in around two seconds or less. I can choose various ways of displaying and ordering the documents it finds to match my needs. I can refine the search to better target my needs or redefine it if it seems not to deliver what I think I need. The documents discovered (and some relevant services offered) are listed with summaries (where available), **details of how to obtain documents** (if not downloadable), the costs etc. **The French and the UK sourced documents are clearly flagged**. Some documents are held by the French and UK providers themselves but others belong to third party providers with whom CONNIE may or may not have reached business arrangements (and, for instance, SSO agreement). **I tick those documents I want and they become part of my "shopping basket"**. After confirming the charges, I automatically retrieve the files I want. CONNIE will generate orders for those documents that are only available by mail.

Finally, my enquiry is stored on the French node against my details so that it is auditable and also to warn me if I (accidentally) attempt to download the same document more than once!

1.3. Requirement specification

Software requirements meeting above mentioned functionalities are of three main types of services: basic services, informative services, descriptive services. Functionalities of use cases are classified according to effort, risk and priority for the development. The last section provides a description of representative services as well as detailed explanations of possible internet business models. Amongst the strengths and opportunities identified is the strong position of participating partners and the clear

need identified by targeted end users participating in surveys. Based on identified requirements we have divided basic descriptions: (1) Core services; (2) Informative services; and (3) Descriptive services. The following types of content will be available within the CONNIE network: directory of content sources, bibliographic information, indexed content through crawler and search engine and interfaces to existing data.

1.4. Conceptual Architecture

CONNIE conceptual architecture (Figure 2) provides a flexible framework [2]. The architecture is divided into four layers grouping corresponding functional units: data layer addressing data storage, core layer establishing CONNIE network, services layer dealing with regulation handling and interface layer providing common interfaces:

Data layer: contains databases, which are based on common data models. Data layer contains information on sources that are used within the system, user specific data, and application data.

Core layer: contains basic services related to general use of the CONNIE system. These services are not explicitly dedicated to the use with building regulations (they enable management of users, data, services, content, etc.). CMS has been used to support the creation, management, distribution, publishing and retrieval of information. The role of CMS is also to serve as a platform for distribution and development as well as reuse of components such as FAQs, records management, subscription, etc. that each can configure into the portal as needed. It is also supported with Web Services technology to integrate with external applications. For the prototype development we have selected the Mambo CMS (www.mamboserver.com) version 4.5.2. In the project the Mambo CMS has been implemented under different platforms and web servers e.g. Apache on Debian Linux and Windows IIS and Apache on MS Server 2003. Several prototypes have been developed in PERL as well as in PHP and JSP. An important part of Core layer is also CONNIe network connector that is described in chapter 2. The component was developed as a standalone application as well as built and deployed as a standard CMS component. DCS has a web interface as well as an open XML access with API described by a WSDL.

Services Layer: is related to the use of regulations where each national portal is independent but through common added value different services can exchange relevant information that is implicitly related to the business.

Common-Value-Added services include sign–on (SSO) and collaborative filtering CONNIE enables new business models and enhanced the use of building regulations. SSO was based on Shibboleth, which is and open source project of Internet2/MACE providing robust architectures, policy structures, practical technologies, and implementation supporting inter-institutional access to restricted resources (http://shibboleth.internet2.edu/). It is based on standards like SAML (Security Assertion Markup Language), and provides mechanism for federated attribute exchange. We have also established a conceptual framework for personalization that will be further enhanced with collaborative filtering.

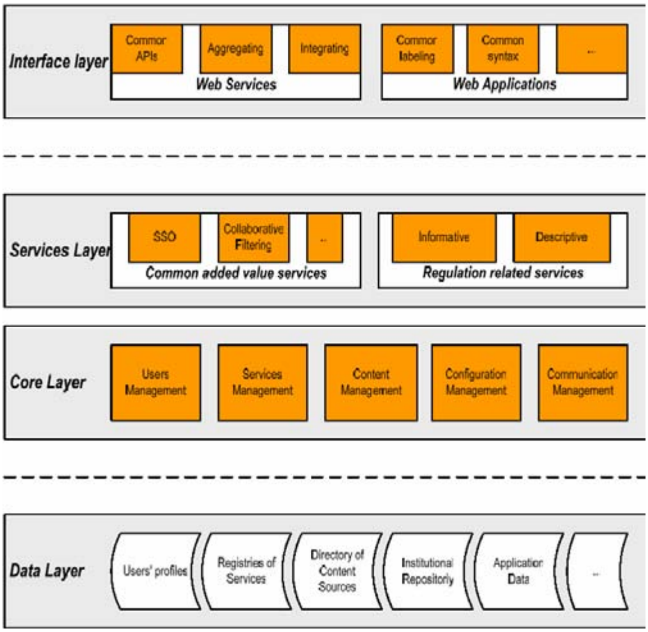

Figure 2. CONNIE conceptual architecture

Regulations specific services include Informative and descriptive services both deal with regulations, but act on the content differently - only the latter are used to interpret the content.

- *Informative services:* provide information about regulations and include IR techniques (search mechanisms, meta-search, news and change notification, clustering, thesauri search, etc.). These services provide information about on regulations. For example search engine consists of several tools including specialized: (1) Crawler with online administration scheduler, deep searching, synchronization with directory of content sources; (2) Indexer with specific "regulation-code" indexing; and (3) Interfaces with specific syntax and query extensions such as clustering, summarization, ontology and thesaurus-based query expansion. Next example is news service: news are extracted from domain-specific relevant international, European and national culling mechanisms for indexing daily news from carefully selected sources with browsing, searching, alerting capabilities, as well as aggregation. Connie search engine was developed based on the Nutch open source search engine with a specialized crawler as well as a complete pluggable php port of Nutch search engine has been developed to be used within the CMS environment.
- *Descriptive services:* describe/extract/interpret the content embedded in regulations (online learning, multimedia presentations, process models interpretation, etc.). Worked examples: these are case based studies - online learning practical material and would provide worked examples that are based on specific building codes and standards. Rule based interpretations: Semi-automatic extraction of rules – detection of conflicts, Rule based interpretation of standards different, Ontology building, which provide Ontology enhanced information

retrieval, Semiautomatic checking of IFC models. Process model interpreted standards: Interpretation of standard with process model depends on type and size of standard. It can be carried out using different modelling techniques such as IDEF0, flowcharts or workflow models. Hypertext and Multimedia interpretation of standard Provide multimedia interpretation of standard Automatic linking of content – interpretation of contents with thesaurus enriched content, Linkage to related material, and Multimedia representation of content. LOM will be used to describe learning material, including multimedia, process models, hypertext representations of standards with features like automatic linking mechanisms [5], rule based interpretations [6], based on RuleML, OWL, or checking methods as demonstrated on IFC model [7].

Interface layer: Users are able to access information through personalized portals, specialized client applications or can use push technologies. Once subscribed at any national node, users are able to access services at any CONNIE node using SSO. CONNIE will provide templates, unified labelling and syntax for its Web applications.

2. Development and Interoperability issues

Interoperability is the ability to use part of system in another system. Parts that are exchanged in CONNIE are: data, users, developments, components and services.

2.1. Interoperability criteria for the CONNIE framework

Above described framework for content mapping in the planned system must be supported by appropriate measures, which can be characterized by:

- *CONNIE Commons.* System interoperability is achieved through common data models, APIs, syntax, and graphical user interfaces. We also deliver content that under common IPR (Intellectual Property Rights), as well as end users can be grouped under common types and context.
- *Decentralized portals.* Each national node provides information on its own sources of information, users, content, application data and services.
- *Flexible conceptual architecture.* Architecture is SOA - Service-Oriented Architecture where all services are defined using a description language and have invokable interfaces used for aggregation and integration.
- *Development and interoperability.* CONNIE is network of EU services that can communicate between each other using common APIs and/or can be accessed through national portals. Networking of nodes is based on services that have three distinctive properties: platform-independence; dynamic invocation; self-sufficiency.

Similar approach was also used for the design of the network of information portals in the CONNET project, which was designed as a set of loosely coupled nodes, operated by the different partners in the project. The idea was to integrate the nodes on both a semantic and technical levels. This idea was taken a step forward as explained below.

2.2. Conceptual approach to interoperability – The CONNIE commons

CONNIE should provide targeted information through a network of services. Following five main models were adopted as a framework for system development [2]:

Common Data Model – Since there are a lot of services that are based on similar data items and deliver similar results, there is a natural need to develop common data models that will be used throughout the services. In the early days of mainframe computer systems, it was common to envision an enterprise-wide "management information system" that mandated a common data model applied to all enterprise information systems. This approach is less stringent than subordinating all systems into some master, all-encompassing system, but it still does require central administration of an abstract and complex model shared by all interacting systems. The attempt to map this common data model into central portal was tempting, but was not shown in the practice to be successful. Since it does not allow different approach and is not prone to adapt to different needs and capabilities.

Common Applications Programming Interface (API) – The CONNIE Application Programming Interface (API) plays a significant role in operation of the CONNIE network. Firstly, it is common to all the national nodes that operate in the CONNIE network so the same functionality can be expected from each independently operated national node. Secondly, it enables the CONNIE national nodes to share and exchange information and appear seamless to the end-user as a single virtual service. Thirdly, it enables communication with trusted partners and/or third parties to invisibly re-use information provided by the CONNIE services. The CONNIE architecture and API exposes much of the CONNIE solution functionality using a layered approach and as core and optional services enabling flexibility in its implementation. These interface are described using

*Common syntax/user interface***.** The CONNIE system is oriented towards improving information retrieval (IR) of building regulations as well as in the ways the content is presented to the end user. Interfaces represent the bases for the human-computer-interaction and therefore represent an important aspect of the successful system. The goal was to define both: (1) specialized syntax for regulations retrieval, and (2) a set of reusable interfaces that could be used as templates for typical content. An important aspect of the CONNIE systems is searching, which must address two types of interfaces for SQL and IR queries. Different approaches are needed since the first is oriented towards database querying resulting in tables matching specific criteria, and IR querying of large collections delivering ranked results. The latter is usually used format for all major public and desktop search engines. The goal of the syntax is to cover specific needs that are related to building regulations and the context in which they are used.

Common IPR model. CONNIE content IPR is based on CreativeCommons.org, which enables copyright holders to grant some of their rights to the public while retaining others through a variety of licensing and contract schemes including dedication to the public domain or open content licensing terms. The intention is to avoid the problems current copyright laws create for the information sharing. The project provides several free licenses that copyright holders can use when releasing their works on the web, which can also be applied to building regulations related material. They also provide RDF/XML license metadata, that makes it easier to automatically process and locate licensed works.

2.3. Assuring technical interoperability

The work was carried in two phases: (1st phase) establishing infrastructure for CONNIE network with core services and the development of the most important services, (2nd phase) developing and extending common and national CONNIE node' services.

The CONNIE system enables quick adoption of new solutions. In order to achieve that the following requirements were considered to select a programming environment:

- Operating system independence: Supporting more Web Servers (IIS, apache) and Scripting Languages that will be run at server side. PHP was selected as preferred scripting language due to platform independence, support for databases and other factors.
- Database engine: support for open source and commercial SQL compliant engines.
- Application server: Strong support from the development and end user community - if possible from open source community.
- Open APIs for syndication of content from nodes. These criteria lead to selection of mambo CMS open source system for content management.

The technical implementation development process is divided into phases:

- Rapid prototyping: We have used several tools that enable rapid prototyping of specific network services and components in order to demonstrate possible functionality and population with data for testing purposes we used languages such as perl, jsp and php.
- Refinement of data models, APIs and interface functionality: Through rapid prototyping and testing we refine data models, APIs and functionality.
- Development of final production components: After we have agreed on common data models and prototypes we will develop final production components.
- Implementation at local nodes: Stable components are deployed at local nodes.

In order assure interoperability and to achieve consistency on the data level we have defined a set of common metadata, where field entries are controlled through agreed vocabularies. Latter are used to improve the effectiveness of information storage and retrieval systems, web navigation systems. The primary goal of vocabulary control is to in the description of content objects and to facilitate retrieval. There are many different kinds of controlled vocabularies. The common ones are:

- Preferred terms ("pick lists"): frequently used to display small sets of terms that are to be used for quite narrowly defined purposes such as a web pull-down list or list of menu choices.
- Synonym rings: used behind-the-scenes to enhance retrieval, especially in an environment in which the indexing uses an uncontrolled vocabulary and/or there is no indexing as when searching full text.
- Taxonomies: often created and used in indexing applications and for web navigation. Because of their hierarchical structure, they are effective at leading users to the most specific terms available in a particular domain.
- Thesauri: these are the most typical form of con-trolled vocabulary developed for use in indexing and searching applications because they provide the richest structure and cross-reference environment.

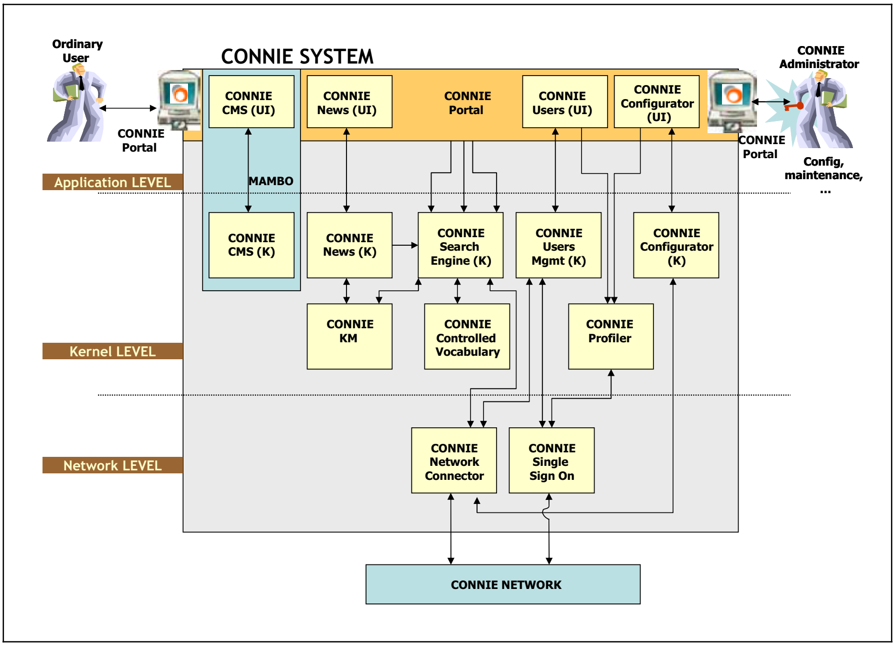

Figure 3. Interfacing components in the CONNIE network

2.4. Networking information portals

Decentralized Portals for the CONNIE network where seen as the only feasible solution since the idea of centralized portal for all EU regulations is unrealistic due to the following facts: applicability of laws and standards is geographically dependent, interfaces to several sources are required, partner institutions already have their own user accounts, specific content, and have established business and legal arrangements with sources of regulative information, as well as have invested into technical solutions for content delivery. These are only some indicative requirements for the interoperability of nodes forming the network enabling effective communication among different national sources where each node can communicate with other nodes and can establish flexible B2B business arrangements.

The creation and instantiation of this network is performed by the CONNIE Network Component (CNC), which is formed by three main elements: the Network Manager, the repositories of Services and Nodes, and a set of Web Services (Figure 4). The Network Manager is the heart of CNC. The two repositories store respectively information about each one of the CONNIE services currently available within the whole CONNIE network. Finally, the set of Web services are grouped into three classes, namely services related to the operation of the CONNIE network, services related to the CONNIE services, and auxiliary services.

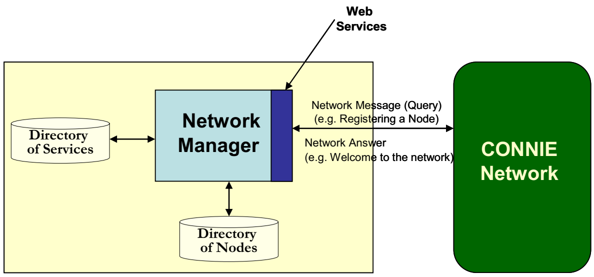

Figure 4. The CNC Conceptual Architecture

When a CONNIE Node is activated, the CNC must be triggered in order to connect the respective CONNIE node into the CONNIE network. In order to do that, CNC provides the *Startup* service, which is used to make available (to the whole network) the services provided by the Node itself and, at the same time, to gather information about the current status of the CONNIE network (nodes available, services offered, etc.). After that, the CNC keeps waiting for requests coming from other CONNIE nodes. The CNC must be configured before starting its operation. The configuration process is about:

a) Defining variables for accessing the local Database: it includes four variables, namely *Host ID* (server Identifier), *Database identifier*, *DB Administrator*, and *Password*.
b) Filling in the network-related information for each CONNIE node, i.e., IP and port number.

The CNC services related to the operation of the CONNIE network are the following: *Ping* (check if one given node is running), *Hello World* (inform the CONNIE network that one given node is alive) and *Registering Myself* (used when a CONNIE node joins the CONNIE network for the first time).

The CNC services related to the CONNIE Services can operate in a synchronous or asynchronous way. The synchronous services are: *Register a new CONNIE service* and *Deprecate a CONNIE service*.

The need for the asynchronous service comes from the fact that the commercial side of CONNIE is very relevant. When a CONNIE user wants to use a service provide by a given Node, we expect that this need is going to be fulfilled and supported through a commercial agreement. Therefore, the first time a given service is called by an 'unknown' user, the Node offering the service must check if the commercial agreement was signed and if that user can really have access to the requested service. This operation can take some time (minutes or hours), so we think it must be implemented in an asynchronous way. Therefore, the following two services support this need: *Request access to services* (ask for permission) and *Request access to services* (gives an answer: granted / denied).

The CNC also relies on the following auxiliary to perform its tasks: *List Online Nodes*, *List All Nodes*, *List Local Services*, and *List All Services*.

Finally, the CNC handles the two directories (services/nodes) that respectively provide the necessary information related to the CONNIE network (Node Id, IP address, etc.) as well as to the CONNIE services (Service ID, Service Provider, WSDL specification, etc.).

3. Conclusion and outlook

The CONNIE technological solution incorporates an open extensible framework that enables both implan-tations of flexible and adaptable business models be-tween individual CONNIE partners as well as addi-tion of new nodes in participating countries or in other countries not currently as part of the CONNIE consortium. Each consortium member is required to provide and maintain a minimum level of compatibility across the CONNIE network.

The compatibility includes technical appliance and functionality available at each node, type and quality in content, implementation of controlled vo-cabularies and classification systems and exploitable business arrangements. Future CONNIE Network member requirements broadly additionally address:

- Institutional requirements where membership is restricted to institutions from the construction sector with a standing reputation and industry wide audience.
- Legal and IPR requirements that seek to en-sure fair and transparent practice according to EU and national legislations.
- Operational requirements that enable CONNIE network member monitoring and maintenance where the status of each node is monitored through CONNIE node profiles.

Moreover, CONNIE Network members can en-hance user facilities by implementing additional specialist, value-added services. The results presented in this paper cover the first phase of the project. The approach was proven as very effective, and shows a great potential for informative and descriptive services.

4. Acknowledgments

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Collaborative, Mobile and Multimodal Working Environment

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Autonomic Workflow Management in Agent-based Structural Health Monitoring Systems Using Graph Theory

Kay SMARSLY[1], Karlheinz LEHNER, Dietrich HARTMANN
Institute for Computational Engineering (ICE), Ruhr-University Bochum, Germany

Abstract. This paper presents an approach towards autonomic workflow management within a distributed, agent-based structural health monitoring system. This monitoring system is currently being developed at the Institute of Computational Engineering. Its global aim is to support the involved human experts in monitoring safety-relevant civil infrastructures by an artificial organization of several cooperating software agents. For the purpose of managing the workflow, Graph Theory – suitable to mathematically represent discrete distributed systems – is utilized by self-controlling software agents. To this end, software agents are regarded as distributed, self-contained entities and capable of making independent decisions. However, by applying the Graph Theory, and in particular Petri Nets, for controlling software agents, the agents just carry out instructions of a "centralized planning capability" that provides workflow specifications but cannot act independently. Thus, a layered approach is outlined allowing benefits from both the independent agent nature and the advantages of centralized planning.

Keywords. Structural Health Monitoring, Software Agents, Graph Theory, Autonomous Computing, Workflow Management

Introduction

Structural Health Monitoring (SHM) aims at providing fundamental knowledge on the behavior of structures, in particular civil infrastructures in response to external impacts and deteriorations. The behavior is analyzed by means of measured data. As a result, SHM provides an improvement of quality as well as safety by examining and locating potential damages and degradations of a structure. Thus, lower maintenance and lower rework costs can be accomplished.

Furthermore, by applying ***automated*** SHM systems, structural anomalies and their progressions can be directly identified. Also, the magnitude of detected damages can be enormously decreased by duly interventions: By automatically analyzing the acquired measured data, damages can be detected at early stages and the reliability of structures be assessed in real-time. A lot of fundamental research has already been done in the field of SHM, in the last years. For example, in the area of dam monitoring, an automated monitoring system is currently being developed [5] that represents the current state of research in dam monitoring. Thereby, software agents are controlled

[1] Corresponding author. Institute for Computational Engineering (ICE), Ruhr University Bochum, Universitaetsstr. 150, 44780 Bochum, Germany; E-mail: k.smarsly@gmx.net.

and coordinated by human actors in order to solve specific tasks within the monitoring problem in a reactive fashion.

As an advancement of automated monitoring, ***autonomous*** monitoring tries to largely coordinate software agents by software agents instead of human actors. In this context, autonomy includes *adaptability*, *learning aptitude* as well as so called *self-healing effects*. Hence, a significant benefit compared to automated monitoring is achieved. In particular, an improved and systematic support of the involved human actors is obtained. Furthermore, potential anomalies will be detected on the spot. Reports concerning the structural state can be provided in time and, then, submitted to the human actors.

This paper demonstrates how an approach towards agent-based autonomous monitoring of civil infrastructures can be implemented using autonomic workflow management within an agent-based monitoring system. A focus is lain on Graph Theory, which is used for controlling the coordination of agents by agents.

1. General workflow in Structural Health Monitoring

With respect to workflow management, numerous research has been done on modeling, simulating and controlling effectively the execution of activities within processes [11, 12]. The goal of workflow management is to define specific work scenarios or *cases* and to handle them as efficiently as possible. Cases are handled by executing *tasks*, causally depending on each other, in a specific order. A typical workflow in SHM is in general characterized by (i) acquiring and storing structural as well as environmental data, (ii) analyzing these data by using appropriate analysis techniques and (iii) informing the responsible human actors by means of reports on current structural states or on arisen identified structural anomalies.

1.1. Data acquisition

Acquiring data on structural and environmental behavior requires the equipment of a structure and its environment with appropriate sensory devices. Customarily, in modern monitoring systems the installed sensors are connected to a logger device (or embedded in a logger device) such that the sensors and the logger device build a sensing unit. Logger devices, then, sense signals and finally have, after filtering and converting, measured values to be stored in their internal memories. Finally, the measured values will be passed through to a centralized data acquisition unit with a local database. This could be, for example, a remote computer located near the observed structure connected via the Internet or another suitable connection for further processing.

For a professional data acquisition, a large number of different sensing techniques exists. In this context, a new field of interest is the application of distributed networks of wireless sensing units [2], capable of acquiring measured data, pre-analyzing the data using embedded damage detection algorithms, and transmitting all data in real-time.

1.2. Data Analysis

Having acquired measured data, the data is used to extract information that enables the detection of anomalies in structural behavior. Generally, the suitability of data analysis

techniques strongly depends on the particular monitoring objective and on different processing and analyzing frequencies (e.g. short-term or long-term analysis). With respect to a computer-based implementation, suitable approaches are possible: For instance, "classical" statistical methods allow for analyzing the short-term behavior and Data Mining and Machine Learning techniques enable an accurate identification and prediction of trends concerning the long-term behavior of a structure.

1.3. Documentation

In a concluding step, the analysis results are summarized in safety reports – usually by using well-defined rules. A safety report summarizes a structure's condition during a observation period. For example, it includes some characteristic time series and describes the results of accomplished data analyses along with a prognosis of a structure's condition.

2. Agent-based monitoring

Based on the analysis of the monitoring workflow, each introduced monitoring task is mapped on individual software agents. Basically, each of these agents, called *task agents* T, is responsible for solving a specific task within the agent-based monitoring system. Such an agent system is currently being developed at the ICE [10] aimed at the support of human experts for monitoring safety-relevant civil infrastructures.

Since a simple mapping of monitoring tasks on software agents is not sufficient for providing a sophisticated real-time monitoring of civil infrastructures, the task agents cooperate with other agents in the same agent system. This approach leads to

i. *Cooperation agents* C that function as "personal assistants" by representing the specific organization of the human experts. Thus, each of the cooperation agents is assigned to one human actor (e.g. a head of department, a chief engineer or technicians) in order to support that actor proactively in solving his specific tasks. Consequently, a cooperation agent provides an interface between a user and the agent system.
ii. *Project agents* S are responsible for providing specific structural information associated with the observed structure.
iii. *Wrapper agents* W encapsulate external software (e.g. database systems) as well as hardware, such as sensory devices, and make them available to the agent system.

Therefore, the whole set of involved software agents can be formally described as

$$A = \{T, C, S, W\}, \tag{1}$$

interacting in an environment

$$E = \{A, O\}, \tag{2}$$

with $O \subseteq A$ as a set of objects to be perceived, created, destroyed and modified by the agents using several operations Op (in particular agents' actions). Objects and agents as well as inter-agent coherences are described in terms of an assembly of relations R.

In total, the agent system is defined as

$$As = \{E, R, Op, U\}, \tag{3}$$

where U is a set of operators representing system modifications as well as the environment's reactions to this modifications.

As a consequence, both the measuring infrastructure (hardware) and the agent system (software) build the agent-based monitoring system.

3. Autonomous workflow management using Graph Theory

If several software agents must cooperate in a common environment E, a coordination is required. By that, the task of coordination comes into the play: Concerning the individual agent categories introduced, a selected agent amongst the cooperation agents ($c_1 \in C$) is responsible for the coordination of its co-agents. The agent c_1 acts as a "personal assistant", assigned to the human supervisor who is finally responsible for monitoring. Accordingly, this agent must have appropriate knowledge on the workflow for managing the monitoring problem.

In detail, the agent c_1 is considered as a "centralized planning device", organizing and synchronizing all the activities of the co-agents. It allocates resources and re-organizes the agent activities autonomously in case of contingencies. This centralized planning implies that co-agents are not involved in managing the workflow, rather they are responsible for executing specific (monitoring) tasks, solely.

From a mathematical point of view, the coordination can be appropriately modeled based on Graph Theory supporting complex concepts such as concurrency. Basically, a graph is a symbolic representation of a network including its connectivity. In the representation of workflows, graphs are used to describe work items in terms of nodes N and the links between work items in terms of edges F. Each graph is then

$$G := (N, F), \tag{4}$$

whereby a directed graph is a set of nodes connected by ordered pairs of "directed" edges. Based on Graph Theory, classical Petri Nets [8] can be understood as directed bipartite graphs containing two node types, (i) places P describing system states (visually represented by circles) and (ii) transitions T describing activities, actions, events, etc. (represented by rectangles). Places P and transitions T are then connected via directed edges F. Connections between two nodes of the same type are not permitted. Consequently, we have a quadruple

$$G = (P, T, F, M), \text{ where} \tag{5}$$

$P = \{p_1, p_2, \ldots p_{|P|}\}$ is a finite set of places,
$T = \{t_1, t_2, \ldots t_{|T|}\}$, a finite set of transitions ($P \cap T = \emptyset$), and
$F \subseteq (P \times T \cup T \times P)$, a set of edges (flow relation).

In addition, places P may contain a number of tokens M (depicted as dots). Tokens are responsible for the execution and, hence, for the dynamics in the system. In the agent system, data exchange between agents can be represented by these tokens. Thus, if a system state (and data) changes, transitions consume tokens from multiple input places, act on them, and transfer tokens to multiple output places. However, transitions are

only allowed to act on tokens (by a process known as "firing"), if they are enabled, i.e. the following two conditions are met.

i. In each input place a required number of tokens appears.
ii. In every output place the number of tokens falls below a defined threshold.

Since more than one transition in a net can fire at the same time, Petri Nets are appropriate for modeling the concurrent behavior in distributed systems. With respect to the workflow management within the agent-based monitoring system is modeled by transitions while states are modeled by places. A typical Petri Net defining the monitoring workflow looks like figure 1. Having collected data, the measured data will be analyzed by comparing them to a set of reference values. Subsequently, the analysis results are stored for corresponding reports. The execution of this net may be repeated multiple times or terminated.

Refining the workflow progressively leads finally to a detailed basic workflow representation, obtained by extending the Petri Net iteratively in further steps. To give an example, taking the workflow representation in figure 1 as a basis, the transition "collect_data" can be substituted by a more detailed subnet (see figure 2).

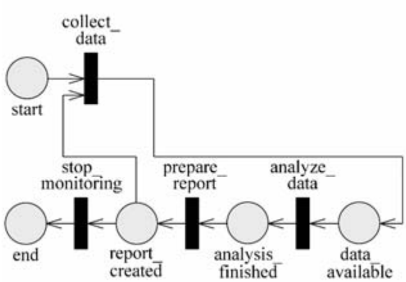

Figure 1. Exemplary representation of the monitoring workflow.

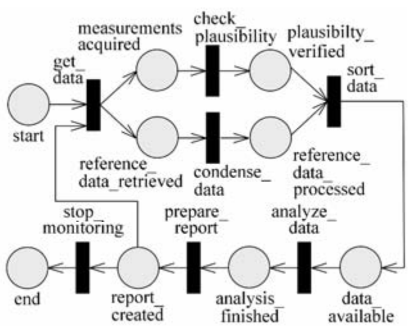

Figure 2. Refining the Petri Net.

By that, two parallel routes are added, which are responsible for the acquisition of new measured data from the considered structure and the application of reference data coming from a database.

Having defined the workflow of the agent communication in all details, the completed model is based upon a *coordination layer* (see figure 3): This layer encompasses the definition of the global coordination of the involved agents. Also, the complete network of monitoring activities and states is encapsulated.

Figure 3 shows that further refinements lead to a more granulated net, containing the complete agent conversations. This refinement is mandatory because the agent conversations are the ultimate basis of agent-based workflow coordination. At that level of detail, tokens again represent data (messages exchanged between the agents) and edges represent message passing (however not necessarily physical message passing between agents). According to the earlier discussion, transitions stand for message processing units, and places represent processed messages, i.e. the state of an agent conversation (see also publications [1, 9]).

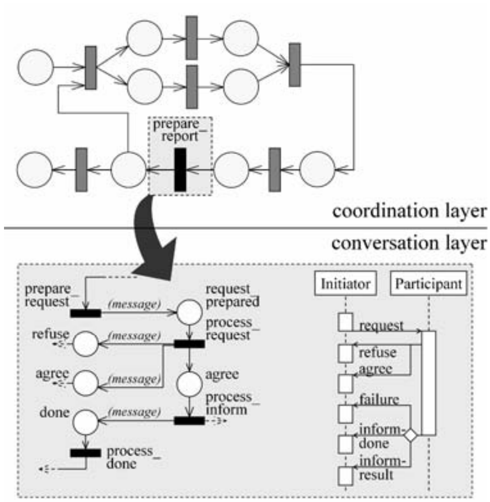

Figure 3. Coordination layer and conversation layer.

Figure 3 exemplifies the refined transition “prepare_report” that represents the preparation of a safety report: The first step in developing a safety report is the generation of a request (“prepare_request”) sent by the report agent (called task agent t_1) to the analysis agent (called task agent t_2) to obtain data analyses for the safety report. The conversation between two or more agents is modeled on a very detailed level and is regarded on a *conversation layer*. This layer defines the detailed communication sequences between all involved agents. Fortunately, there exist numerous established interaction protocols already defined by FIPA [3]. For the example described above, the right hand side of figure 3 shows the depicted conversation using the FIPA Request Interaction Protocol [4] in terms of a sequence diagram.

As a matter of course, each agent within the agent system (i) is able to converse with other agents by using interaction protocols, and (ii) has its own aim to accomplish a given task. As a result, the conversation between two or more agents (located on the conversation layer) can be handled by the involved agents themselves. Then, the agent that is responsible for autonomic coordination (the agent c_1) does not need to care about conversation details. Its responsibility is only applying knowledge about the global coordination aspects. By that, the agent c_1 can easily react on exceptions and contingencies within the system, and adapt the workflow by redefining the net on the coordination layer.

4. Application example

This section introduces in short, how the previously described approach was evaluated within the agent-based monitoring system (technically based on [6]): The agent c_1 was prototypically implemented using the introduced mechanisms for workflow management. c_1 first creates Petri Nets that are abstractly located on the global

coordination layer. For that purpose, the agent uses a simple knowledge-base, containing a specification about a "standard" net for controlling the monitoring workflow. Moreover, the knowledge-base contains various specifications of exceptions in the workflow representing contingencies to be updated on demand. Possible contingencies are, for instance, the breakdown of agents, a hardware defect of sensory devices or structural anomalies.

The generated Petri Nets are then used to coordinate the involved agents. Hence, the agent c_1 is responsible for the global workflow management whereas details of how to accomplish the several tasks within the workflow are managed by the particular agents themselves using their own knowledge. Within first test runs of the agent system, data acquisition and analysis have already been simulated. Up till now, however, a real structure has not been connected.

Figure 4 shows an extract of the agent's GUI containing a visual representation of the generated "standard" net as well as some communication details. Using this net, the agent c_1 initiates the accomplishment of the previously defined tasks by instructing the task agents. In figure 5 the simulation of a conversation, i.e. the creation of a safety report is shown. In this case agent c_1 as well as two task agents, the report agent t_1 and the analysis agent t_2, are involved: The agent c_1 instructs the report agent t_1 by using its knowledge in the communication layer to create a safety report. After agreeing, the report agent tries to establish a conversation with the analysis agent t_2 to obtain the latest analysis results. For that purpose, both the report agent and the analysis agent are using defined interaction protocols. After inserting the results in the report, the report agents informs the agent c_1.

As already mentioned, the agent c_1 has been designed to coordinate the workflow autonomously. Therefore, it is able to react on exceptional, abnormal states in the system. To test the ability of reacting to those contingencies, the connection to one of the task agents (the data acquisition agent t_3) was disrupted simply by terminating agent t_3. As a reaction, the agent c_1 constructs a new net defining an adapted workflow for solving the problem of the disconnection. Hereby, a simple fault management could be carried out for detecting, isolating, and correcting malfunctions. In the case of a malfunction, a warning message has to be sent to the human actor to respond to this situation appropriately.

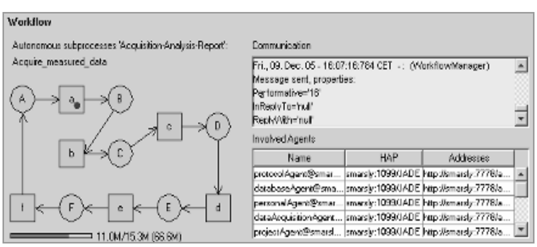

Figure 4. Generated Petri Net for workflow management.

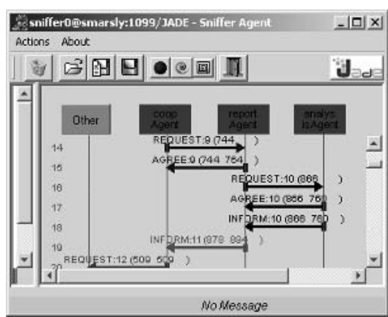

Figure 5. Corresponding agent communication.

5. Conclusions

A workflow management approach based on Petri Nets and its application to an agent-based monitoring system has been discussed. The effective scientific contribution of the presented work is the transfer of established scientific methods and autonomic aspects to a civil engineering problem.

It has been demonstrated that the division of workflow management into two different layers, a coordination layer and a conversation layer, allows for a centralized planning and also for independencies of agents. The involved task agents have been instructed by a superior coordination agent, and solve their tasks independently according to their own objectives. A specific agent within the system is responsible for an autonomous coordinating of the monitoring workflow and for managing of exceptional system states, e.g. malfunctions of sensory devices or breakdowns of particular agents. The management of such contingencies is basically carried out by generating new nets, during run-time, in order to adapt the workflow to exceptional situations.

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Developing a decision-making framework for effective collaborative working

Mark A SHELBOURN [a,1], Dino BOUCHLAGHEM [a], Chimay ANUMBA [a] and Patricia CARRILLO [a]
[a] Department of Civil and Building Engineering, Sir Frank Gibb Building, Loughborough University, Loughborough, Leicestershire, LE11 3TU, UK

Abstract: The new millennium has seen widespread recognition that the construction industry must embrace new ways of working if it is to remain competitive and meet the needs of its ever demanding clients. Project collaborations and collaborative working have increasingly become more important in construction projects. However, it has been argued that perhaps they are not being used to their full potential and in the correct context. The industry has shown a need for simple and efficient (shared) processes to help in the planning and implementation of effective collaboration. Much of the recent work on collaborative working has focused on the delivery of technological solutions, through Web-based systems (e.g. extranets), Computer Aided Design/Drafting (modeling and visualization), and knowledge management technologies and systems. However, recent outputs have displayed a better understanding by many researchers and leading industrialists that effective collaboration does not result from implementing technological solutions alone, with equal (or more) consideration needed for the organisational and people issues. Work currently being undertaken at Loughborough University aims to demonstrate this importance through the development of a decision-making framework and supportive tools to effectively plan and implement collaborative working in construction projects/organisations. This paper reports on the development of the prototype framework.

Keywords: Effective collaboration, construction, decision-making framework, organisation and people

1. Introduction

"Collaboration is not a natural way-of-working for everybody!" Despite the enormous groundswell of interest in partnering and alliancing in recent years, there has been comparatively little research that has set out to investigate systematically the nature, feasibility, benefits and limitations of forms of project stakeholder collaboration [1].

Since the 1980s many organizations and individuals have considered electronic collaboration of distributed teams as a means of achieving higher productivity and

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[1] Post Doctoral Research Associate, Department of Civil and Building Engineering, Sir Frank Gibb building, Loughborough University, Loughborough, Leics, LE11 3TU, UK. Phone +44(0)1509228745, FAX +44(0)1509223945, m.a.shelbourn@lboro.ac.uk

competitiveness, thereby improving the quality of their work products [2]. Research has observed that the current collaboration tool landscape is improving but at the same time is fragmented and lacking comprehensive solutions [2]. Many of the recent developments of collaborative working tools have focused on the delivery of technological solutions with a focus on the web, i.e. extranets, CAD (modeling and visualization), and knowledge management technologies and systems [3,23].

However, technology by itself is unable to provide a comprehensive answer to working collaboratively [4,5,6,7]. This may be because cooperative tasks in teams are increasing, and as a consequence the use of collaborative systems is becoming more pervasive [8]. Approaches to collaborative working that purely focus on information technology have been seen to be less than successful, unless the organisational and people issues are considered as part of the implementation process [9,10,11,12,13,14].

Implementing ICT into construction organisations also requires the bridging of many cultural boundaries [15,16,17]. Managers of ICT implementations have to consider the barriers within the workplace that affect such introductions, i.e. the apprehensive nature of individuals to change, with a more strategic approach [18,19,20,21,22].

This need is currently being considered in research at Loughborough University in the UK. A project entitled: "Planning and Implementation of Effective Collaboration in Construction (PIECC)" is aiding project managers in construction organisations, throughout the supply chain, to introduce more balanced collaborative working into their projects. The remainder of this paper will summarize results thus far, before concentrating on the development of a prototype decision-making tool for the effective planning and implementation of collaborative working in construction projects/organisations.

2. PIECC – Introduction

The PIECC project has a focus on supporting strategic decision-making by highlighting areas where collaborative working can be improved incorporating the organisational (business), project and users' needs. When carefully planned, and if based on informed decisions, it is believed that policies and protocols will help organisations improve their collaborative working, achieve better benefits from it, and maximize the use of tools and techniques that are currently commercially available.

In order to achieve this focus, a number of different methods have and will continue to be adopted. These are:

- Use of published sources – through an extensive literature review to establish current 'state-of-the-art' practice on collaborative working – and associated areas of interest – both in construction and other industries.
- Field studies – these have been conducted to establish current practice for collaborative working. The studies used a questionnaire, semi-structured interviews (with identified key personnel) and case study examples from the collaborating organisations, to elicit requirements for collaborative working, and key issues to be considered at the organisational and project user levels.
- Use a 'develop-test-refine' strategy (action research) – to improve the prototype iterations. This is achieved with a project steering group (industrially focused) that comments on iterations of the framework and supporting material.

3. PIECC – Current State of the Art

A comprehensive literature survey was conducted using desktop study techniques to determine the current state-of-the-art of collaborative working in the construction (and other relevant) sectors. Complimenting the collaborative working review, two other specific subjects: collaboration technologies [24] – including GRID technologies; and the change management implications of implementing and using new technologies for construction organisations [22] were also included in the survey.

Results showed that there are many definitions of collaborative working. Some incorporated the word "concurrent" in terms of the approach and activity, and "collaborative" in terms of ownership [25]. The difficulty in determining a single definition led the research team to describe the different forms that collaboration may take. Anumba et al. [26] described four modes of collaboration – 'Face-to-Face', 'Asynchronous', 'Synchronous Distributed', and 'Asynchronous Distributed', and typical forms of use in the four areas have been described by Attaran and Attaran [27].

The state-of-the-art survey concluded that for an organisation (or organisational unit) to 'effectively collaborate' there must be a balanced harmonisation of three key strategies: business, people, and technology, split on a 40/40/20% basis. Six key areas must be represented in the three strategies. They are:

- **Vision** – all members of the collaboration agree on the aims and objectives;
- (Stakeholder) **Engagement** – managers need to ensure that all key participants are consulted as to the practices to be employed during the collaboration;
- **Trust** – time and resources are needed to enable stakeholders to build trusting relationships;
- **Communication** – a common means of communication is decided by all key participants in the collaboration;
- **Processes** – both business and project, that describe to all key participants how the collaboration is to work on a day-to-day basis;
- **Technologies** – an agreement on those to be used to ensure the collaboration is easily implemented and maintained.

Effective collaboration is only achievable through the innovative design and development of a more balanced 'collaboration strategy', that does not rely solely on ICTs. As yet there is little evidence of such a 'strategy' existing that prescribes to project managers effective ways of implementing and managing collaborative projects. To develop a strategy the PIECC project produced a questionnaire and conducted a number of interviews with key industrial representatives. The next section summarizes the results of these questionnaires and interviews

4. PIECC – Industry Needs and Requirements

The project team developed a questionnaire and conducted a number of semi-structured interviews to elicit the needs and requirements for effective collaboration from key personnel in the construction industry, see [3,23] for more detail. Table 1 shows a summary of the needs and requirements that a collaboration strategy must address.

Armed with these key needs and requirements the research moved to developing a prototype decision making framework. This work is described in the next section.

Table 1: Summary of requirements for the prototype decision making framework.

Category	Requirement
Model	"…a recognizable model for collaborative working does not exist at this time – it needs developing to enable a move forward…" "…must build upon work being done in other aspects of collaborative working – the AVANTI programme for example…"
Process	"…processes that enable participants to agree a common vision & priorities for the collaboration – a route map for how the project is going to proceed, and must include suitable time for review of progress against vision & priorities" "…procedures to promote trust in the collaboration – a key person needs to be in charge, they provide leadership, leading (hopefully) to better performance of the team, to build trust within the team" "…a set of communication procedures that all stakeholders should use in the collaboration"
Standards	"…standards that facilitate interoperability between different software and systems – we are fed up with learning a new system for every new project!!" "…suitable (and appropriate) help templates/screens for users to familiarize themselves with the software tools. They are removed when a level of competence is reached"
Good Practice	"…examples of good practice/case study material that shows tangible business benefits of collaborative working" "…evidence of good practice of collaborative working to be published to alleviate frustration of the industry"
Design	"…intuitive interface design of software to reduce the requirement for training of new members of a collaborative project/environment"
Legal aspects	"…clarification of professional liability of information generated. Who is responsible for the information generated and its trustworthiness? A right balance between the technology and professional liability is the issue to building trust"

5. Prototype Development

Having determined the needs and requirements of the industry for effective collaboration the research team moved to developing a prototype framework. Initial discussions revealed a strong idea that there are essentially four key areas that need addressing. These are: 'Define the need'; 'Develop business case'; 'Design and implement'; 'Maintain and reflect'. Intense discussions with the industrial partners and other prominent members of the construction industry revealed that this approach suited the needs of the industry. However, there was insufficient detail of the processes and procedures needed to plan and implement for effective collaboration. It was decided that an iterative approach was needed to develop this idea further. The project planned to conduct three separate iteration cycles of development.

The first iteration built upon the initial idea described above. The research team integrated the 6 key factors for effective collaboration into the four key areas. This resulted in the presentation of version 2 of the framework for comment. This version had the 4 key factors down the left – 'vision', 'trust', 'engagement', and 'communication' – and three processes/procedures across the top. The other two

factors 'process' and 'technology' were included in the processes and procedures across the top. The 'collaboration champion' (appointed as the leader and manager of the collaboration from one of the collaborating organisations) would then decide on wanting information regarding the 'people', 'process' or 'technology' aspect of the key area. In each of these boxes there would be supporting information to aid all participants to understand the associated issues. The additional information pages included a set of 'sub-processes' that showed the what?, why?, who?, and how? for each sub-process. This information is supported with relevant tools and techniques that can be used to complete any aspect of the framework. The research team produced a set of initial supporting pages as part of the first iteration of developments. Information was taken from the literature review, and results from the questionnaires and survey to aid the production of the supporting information.

The results of iteration 1 of the framework development were encouraging from the industrial partners. They commented that they were encouraged by the development, but would the framework not be better served having a more process centric focus? A question that the research team would address in iteration 2. The group were complimentary in their assessments of using additional information to aid the process of effective collaborative working.

The second cycle began with the redesign of the framework to show a more process focus to the framework. This resulted in the development of version 3 of the prototype framework. The framework is split into 3 distinct stages. The first aims to bring together the different organisations involved in the collaboration to 'align their business strategies'. In this aspect of the framework high level decisions are made on determining the need to work collaboratively. Having determined that collaborative working is the way forward, the collaborating organisations (or organisational units) seek approval from senior management and sign a pre-contractual agreement agreeing to work together collaboratively.

As part of this agreement a person or team is chosen as a champion for the collaboration. This person or team has the responsibility of managing the future planning, implementation and management of the collaboration. Resources to aid the champion or team are also decided upon and allocated at this stage. The second stage requires the collaboration champion or team to define the three strategies for effective collaboration. This section in the framework includes a number of processes, reflecting the need to develop a 'people', 'project', and 'technology' strategy to determine the procedures for working collaboratively in the given project. Once the procedures have been determined the collaboration begins and is continuously monitored to make sure that all participants are working in the ways as agreed. Once the collaboration has ended, feedback is given to the business on how to improve current practices.

The end of iteration 2 of the framework development cycle showed that the additional information – how it is presented, and what information is included – is of vital importance to the success of the framework. The project steering group had some reservations on the content of the supporting information, in that it has been written in an 'academic' style. It was agreed that each project partner should take ownership of one aspect of the framework and suggest ways of making the pages more 'industry friendly'. This process enabled the supporting information to become a better supporting tool to the framework. The industry steering group commented that version 3 does represent the key processes and supporting information to enable effective collaborative working, however it has proven difficult to understand how the framework can be used, and where key decisions need to be made.

During a key project progress meeting the research team and industrial partners created a 'rich picture' of how the processes must be linked together in a more usable format. After further discussions the 'rich picture' was transformed into the framework shown in figure 1. This version is the final version of the decision making framework.

The framework has 4 distinct sections where collaborating organisations: set up there business strategy; define a collaboration brief; plan a solution to fulfill that brief, and then implement that solution. The collaborators do this by working from the top of each section through the described processes to form procedures of increasing detail (as they move from the left to the right) for their collaboration. Before progressing to the next phase of collaboration, a decision is needed to determine whether it is feasible to continue or not, dependent on the outcomes of completing the different processes in that section of the framework. If 'no' then the members of the collaboration revisit that section to try and remove the barriers or problem areas as to why the collaboration cannot proceed. If it is perceived that the collaboration can continue then the collaborators move into the next section of the framework to continue to build their procedures.

The next cycle of development will concentrate on assessing the usefulness of the framework in industrial project situations on real construction projects, or in firms where they wish to adopt collaborative working internally. This is a challenging stage and should provide further evidence of success of the research.

6. Conclusions

The work presented in this paper has shown research and development activities that aimed to assist organisations (or organisational units) to plan and implement collaborative working more effectively. The research to date has determined that there are sporadic examples of balanced approaches to collaboration being implemented in the construction sector. However, these rarely take into consideration the business process or human/organisational issues. A need has clearly been identified through the questionnaire and interviews conducted for the research that a more balanced approach to planning and implementing collaborative working is needed. Developments in the PIECC project aim to provide the industry with a framework to allow effective collaborative working to be planned and implemented in projects.

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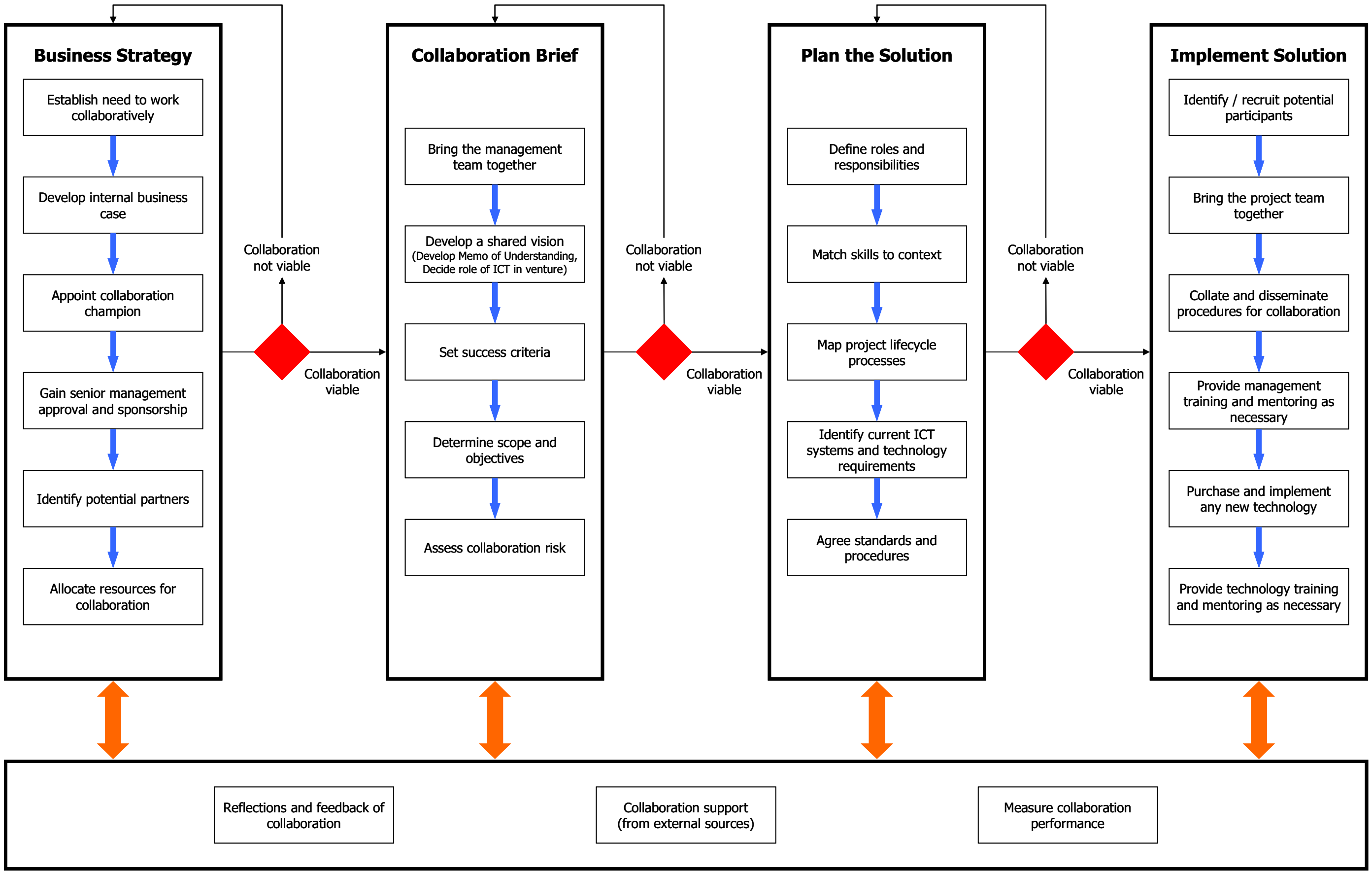

Figure 1: The PIECC decision making framework.

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An assured environment for collaborative engineering using web services

David Golby[a1], Michael Wilson[b], Lutz Schubert[c], Christian Geuer-Pollmann[d]

[a]*BAE SYSTEMS Advanced Technology Centre, Filton, UK*
[b]*CCLRC,UK*
[c]*HLRS, University of Stuttgart, Germany*
[e]*European Microsoft Innovation Centre, Aachen, Germany*

Abstract: This paper describes an application of the TrustCoM environment to support secure contract based collaboration between companies using managed web services. The application scenario describes a consortium of engineering companies that seek to upgrade a customer's fleet of aircraft to provide in-flight internet capabilities. The environment supports the consortium to collaborate so as to take advantage of the market opportunity. In order to reduce the risks of collaboration, the environment provides assurances of the past performance of consortium members, of the current performance of each member to meet their contract and service level agreements, and the secure control of access to resources. As a result of a member's performance, the consortium dynamically reconfigures itself and initiates a collaborative business process that enlists new members to join and contribute to the negotiations with the customer.

Keywords: Virtual Organisations, TrustCoM Project, Collaborative Business Process, Federated Security, Service Level Agreements, Service Oriented Architecture

1. Introduction

Collaborations within the engineering sector are a means of reducing risk in the development and support of highly complex or novel products over the product lifecycle. The collaborators often include tier-1 suppliers, system integrators, component suppliers, engineering consultancies, maintenance companies, and product disposal companies. The size and scope of collaborations may vary considerably over the product lifecycle. In a consortium, each partner can focus on its core competencies but must align the complex collaboration processes with the rest of the collaboration. The virtual organisation (VO) model is therefore a good fit to these many different collaborations, whether they are legally bound as a joint venture, or through a set of contracts and co-ordinated behaviours between a customer and its chain of suppliers.

The aim of the TrustCoM project is to devise a software environment built upon a sound conceptual framework for such VOs which will provide an infrastructure to

[1] Corresponding Author: David Golby, Advanced Technology Centre, BAE Systems PLC, PO Box 5, Filton, Bristol, BS34 7QW, UK; E-mail: david.golby@baesystems.com

support companies' flexible response to market opportunities, reduce lead times to market by maximising the benefits of the concurrent engineering approach, while minimising entry cost to collaborations and ensuring that all interaction within the collaboration is secure. The project will deliver a conceptual model, system architecture with software profiles [1], and a reference implementation which will be evaluated through a set of industrial demonstrators [2]. The industrial demonstrators include scenarios on eLearning and collaborative engineering (CE) - the subject of this paper. The TrustCoM framework and software environment must address issues from many disciplines including legal, socio-economic, security, contract and service level agreements, business process and industrial application domains.

This paper presents the CE scenario and assesses the benefits of TrustCoM technologies to CE in general. We focus on the design phase of the product lifecycle, though the general ideas are applicable to other phases as well.

2. Assured Environment Issues

Within an engineering collaboration, the business risks reduced by collaboration should not be replaced by other risks inherent in the collaboration itself. To maintain collaboration, it is necessary to transfer data between collaborators, and to inspect services and resources which are embedded within each others local IT infrastructure. The decision makers who use this information may range from high level policy makers to engineers who need additional information from their partners if they are to execute their tasks correctly. For example, the management of production processes can be aided if information on the status of a supplier and the progress of an order through the multi-tier supply chain can be correctly monitored. A designer may require critical interface and behaviour information on a partner's subsystem in order to optimize the design of the particular subsystem that he is responsible for. Finally, product and asset information will be needed throughout the operational and decommissioning phases for training, maintenance and product disposal.

TrustCoM reduces the risks inherent in collaboration by addressing the complete collaboration life cycle, and providing assurances at each stage of its operation. The selection of partners is based on assurances of their previous performance in a role – their reputation or supplier qualification. A collaborative business process model (BPM) provides transparency to all collaborators of each others' roles. Service level agreements (SLA) provide assurances of the performance on time, to quality and cost of each collaborator in their role. A contract provides the assurance of contingencies should a collaborator fail to fulfil their role. Claims-based access control is used to provide assurances of the identity of each party, and the authorisation for access to the services and resources that they need to undertake their role – and only access to those services and resources and no others.

3. Architecture and Standards Conformance

The TrustCoM architecture is designed to provide the required assurances, monitor conformance to contract, SLA and BPM, and enforce access controls whilst also minimising the initial costs of adopting it, and maintaining flexibility for each collaborator who may be involved in many other activities at the same time.

A service oriented architecture (SOA) has been adopted to provide flexibility over the geographical distribution of the collaborators. The location transparency of SOA allows collaborators to move the physical location of services as they wish without disturbing the operation of the collaboration. The main risks of exposing a company's services through an open SOA are mitigated through the security assurances provided by the TrustCoM architecture.

The environment has been designed using existing open web service specifications rather than develop the environment entirely as a proprietary system. Although this adds considerable cost and complexity to the design, it also increases the transparency of any implementation, and eases third party implementations of the framework. Both these factors should increase both the trustworthiness of the environment and the probability of its adoption.

A number of possible representations of the framework are possible, but the following diagram shows the sub-system view where the responsibilities of the individual sub-systems that comprise the framework are shown along with their interactions with each other in the context of an executing collaborative business process within the VO. Note that all of the subsystems are embedded within an 'Infrastructural' component that provides many value-adding services of its own in the lifecycle of an application service. This infrastructure is also the means by which messages are mediated between application services.

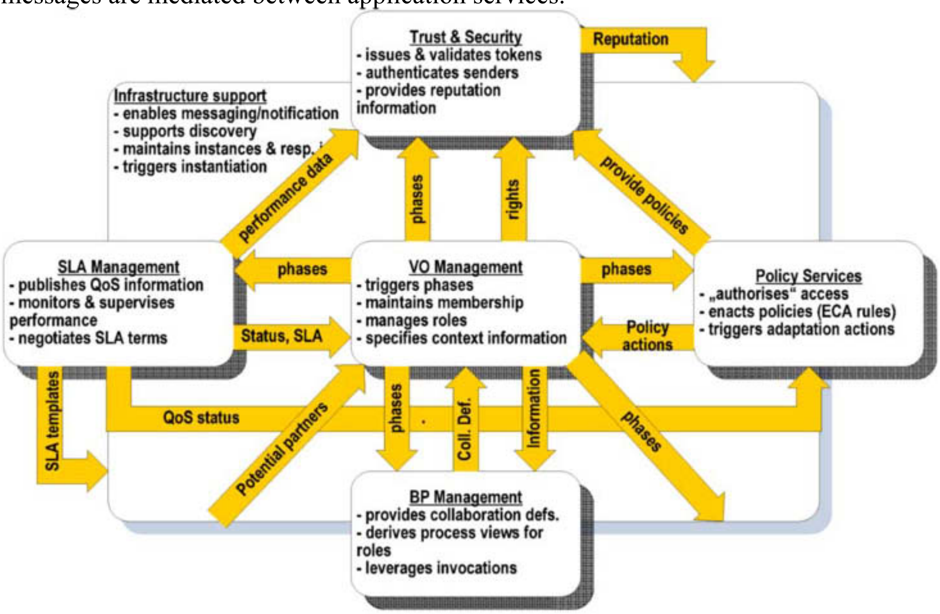

Figure 1. the subsystem segmentation of TrustCoM

In order to minimise integration costs, potential collaborators must satisfy minimal requirements: the application services must be exposed as web services, provide a WSDL interface definition, and maintain a WS-RF resource so that the web service can be managed. This approach maximises the opportunities for providers to re-use services in other collaborations, even outside the TrustCoM assured environment.

The core part of the TrustCoM environment could be operated by a third party whose role is to host the environment for a fee, or by a member of the collaboration.

The business models that drive this choice suggest that for small and short lived collaborations, a third party is more likely to provide the environment, while for large and long term collaborations, such as the collaborative engineering scenario considered here, the second option is more likely to be adopted.

The main role of the environment is to map from a contract in natural language that can be legally binding, down to executable policies, BPMs for each organisation, SLAs for each service and access controls across the distributed services needed to operate the collaboration.

The architecture provides a VO management subsystem to host the natural language contract and hand drafted XML policies matching some clauses, and a database of the VO membership and the access details of their services which are together termed the General VO Agreement (GVOA). The business process of the collaboration is defined by hand in UML, which is refined into WS-CDL and supports conversion into an executable BPEL description for each collaborator that calls their own services and those of other collaborators that they interact with. For each service, the SLA management subsystem stores an SLA. The SLA mgmt subsystem monitors performance of the service and raises events when any aspects of the SLA are breached. The executable versions of policies in the contract are loaded into the policy subsystem where they are executed when events from the security, SLA or BPM subsystems raise events that trigger them. The security subsystem includes security token services (STS), policy enforcement points (PEP) and policy decision points (PDP). PEPs enforce access control policies loaded from the GVOA, accepting security tokens from known STSs such as those operated by collaboration partners. The security subsystem also includes a reputation service that stores a record of the performance of each collaborator (for potential usage across different VOs), and issues reputation status events which can be used to trigger policies derived from the contract if the reputation falls below a threshold. The whole architecture is hosted on an infrastructure which transmits the events between the subsystems as a subscription based notification service.

In the design and implementation of the TrustCoM hosting environment, the following open specifications and standards have been adopted: SOAP, WSDL, WS-Addressing, WS-RF, WS-Notification, WS-Trust, SAML, XACML, WSLA, WS-Agreement, WS-CDL and BPEL. We have created multiple profiles that define how we use combine different specifications: we selected a subset of WSLA to support a collaboration environment; we specify a combination of WS-Trust and SAML to support a VO-centric claims-based security model; we define how XACML should be used for web services and transport formats for policies in XACML; and we define how WS-CDL can be used to represent collaborative business processes between organisations that can be refined into executable BPEL for each organisation.

The overall architecture, design and implementation of the assured environment is designed to meet the needs of a wider variety of business models and collaboration patterns than used in the collaborative engineering application described in this paper, but its operation is being demonstrated, and will be evaluated, in that domain.

4. The Collaborative Engineering Scenario

TrustCoM has developed several industrial scenarios in order to test, validate and refine the TrustCoM framework through the derivation of requirements, testing of the

feasibility of ideas and application of use cases for the verification and validation of the reference software implementation of the TrustCoM framework.

The storyboard for the CE Demonstrator considers the pre-contract phase where a business proposition is made by an engineering consortium to a customer to upgrade its products. The principal actor in the scenario is an existing engineering VO (called 'CE VO') that is responsible for the design and manufacture of a high performance business jet. The CE VO works with a number of different entities, including engineering consultancies, tier-1 subsystem providers (in this case, of the in-flight internet capability) to generate a number of proposals to the customer. The business proposal is to upgrade the customer's fleet to provide in-flight internet and other services in the passenger cabin. The goal of the collaboration is to win a contract that satisfies the customer's requirements, minimises risks involved with delivering the aircraft upgrade and maximises the benefits to the consortium members. During the negotiation process, various parties access information and computing resources hosted by different collaborators to make decisions. For example, the designers have access to asset information systems held by the customer's maintenance provider, while the designs are accessed by an external engineering consultancy. The engineering consultancy itself uses services from other companies, two of which provide High Performance Computing and storage (HPC) services.

Figure 2 presents the top-level view of the actors within the collaboration. From the figure, the collaboration can be recursively broken down into 'sub-collaborations' where for example, the 'Analysis VO' aggregates services from engineering consultancies, software houses and HPC providers to provide an overall capability that could be applied to different engineering sectors. This overall capability provided by the Analysis VO would participate within the overall design cycle to assess designs and possibly help to improve them as well.

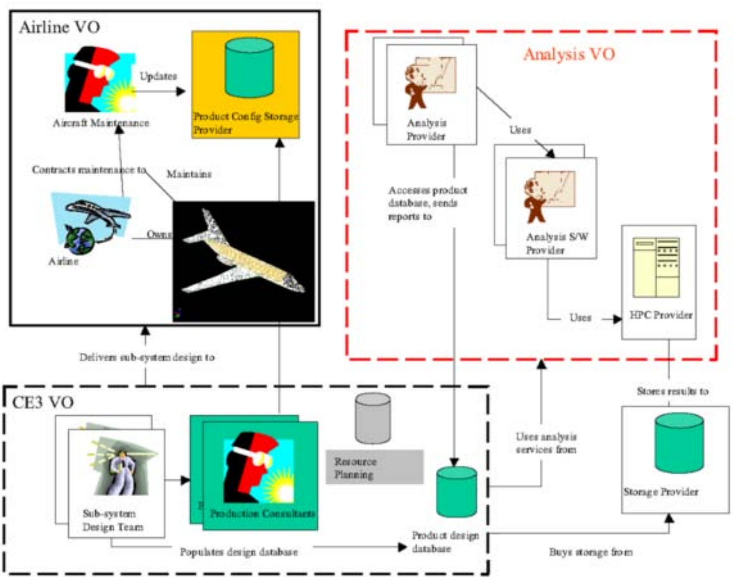

Figure 2. The actors within the CE Scenario

The collaborative business process is a fundamental aspect of the TrustCoM VO model, and this can be expressed as a simplified UML activity diagram shown below in Figure 4. Other collaborative business processes derived from this picture can also be identified at the lower levels of the collaboration as well, e.g., between the HPC and SP services shown in Figure 5.

Currently, the TrustCoM CE Test bed is used to examine particular aspects of the scenario described above in the assessment of the TrustCoM framework. The CE Scenario is considering the following aspects within more detailed studies:

1. Secure business process enactment
2. VO Management and Evolution
3. Infrastructural Aspects

In the *secure business process enactment* study, we use a federated security model to enable collaborators to share their services. SAML tokens with embedded claims are used to protect outgoing messages. Such a token could e.g. contain that *"requestor from partner A of this service has the role 'Analyst'"*, which can be used by domain B to make an access decision. After validating the claims, the service's policy enforcement sends an XACML request to a policy decision point that is used for making the final access control decision. The policy enforcement also ensures that the actual messages are protected appropriately, e.g. signed and encrypted message contents. This separation simplifies application development, because security requirements are enforced by specialised components. Figure 3 shows a simplified picture of these components working with the infrastructure bus in the context of the HPC and Storage Provider service interactions.

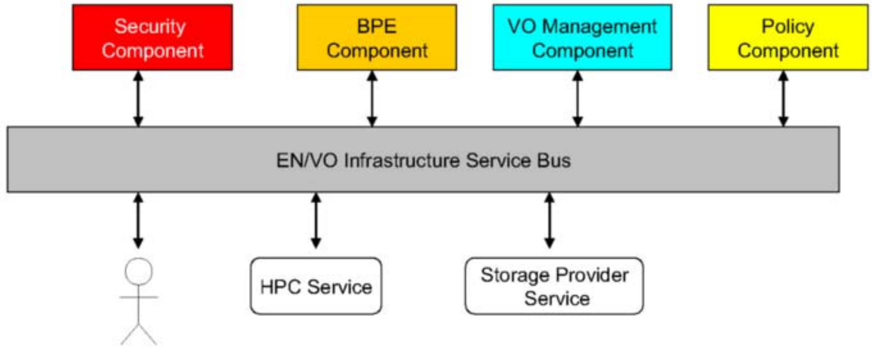

Figure 3. EN/VO infrastructure service bus connecting application services and TrustCoM components

So for example, the outgoing message from the client/Analyst on the far left of Figure 3 will be intercepted by the service bus (the Infrastructural sub-system in Figure 1) and the aforementioned security claim inserted into the message by the Security sub-system. This claim can be validated at the HPC Service provider's site using its own Security sub-system before the message reaches the application service itself. In this way, the clients and service providers can collaborate without having visibility of any intrusive security procedures which are handled by the framework. Securing the message rather than using a private link also gives much greater flexibility and admits the possibility

of, for example, the routing of messages through many domains and over different transport protocols while ensuring end-to-end security of the message.

Secure business process enactment will further consider how the top-level business choreography expressed in Figure 4 as WS-CDL can be distributed as BPEL documents to each collaborator for them to enact. In Figure 3 above, the BPE sub-system becomes the primary co-ordinator of this collaborative business process: it ensures that the application services (eg, the HPC and Storage provider services) are executed in the correct sequence as required in the collaborative business process description that is part of the GVOA. As shown in Figure 1, the BP management component also reports any exceptions to the VO Management sub-system which may take measures (defined by the Policy sub-system) to manage these exceptional events.

This approach ensures that a distinction is made between the public interfaces and message interactions of each collaborator in the collaborative business process, and the private processes that are used for fulfilling the business duties of that collaborator. The EN/VO infrastructure will also provide support for the management of the context of these interactions via WS-Coordination. This is an important ingredient for other value-adding features, such as transaction management, as well.

In *VO Management and evolution*, the problem is addressed of how the VO reacts when individual members such as the HPC service provider violate the agreement binding them to the VO- the GVOA described earlier. For example, the agreed SLA of the HPC service provider within the GVOA could be violated and the performance of that service could fall below a certain threshold. Under these circumstances, a VO policy dictates that the service has to be monitored and messages to and from that service logged to an audit service. Furthermore, a reputation service (part of the Trust and Security sub-system in Figure 1) can be used to record a change in the reputation level of that service – important information that can be used by current or future users of that service as one of many criteria for selecting that service in the VO discovery phase. If the performance level declines further, the current HPC provider could be replaced by an alternative service provider who can take over the same roles and responsibilities. The ultimate aim of TrustCoM is to ensure that this process of discovery of alternative suppliers, their enrolment into the VO and their monitoring can be managed in a seamless, automated way.

Infrastructural aspects will consider how the EN/VO infrastructure can provide means for supporting the 'instantiation' of an application service and its configuration for a particular collaboration or VO. Application services can therefore be deployed once and 'instantiated' and configured for many different engineering collaborations.

The following diagram shows the top-level business collaboration that is enacted within the collaboration described in Figure 2. This is a view of the collaboration that is familiar to engineering project managers who ensure that the business and engineering teams are co-ordinating their activities correctly.

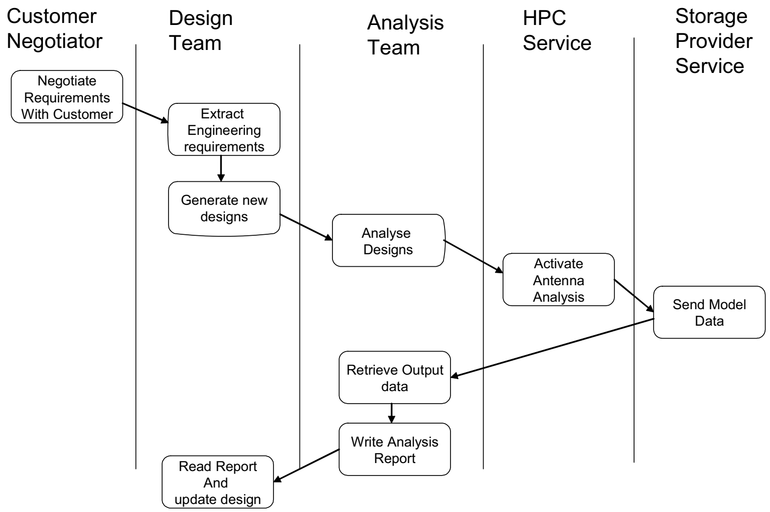

Figure 4. The Top-level collaborative business process in the CE Scenario

Figure 5 shows the collaborative business process fulfilled by the HPC and SP services. This operates at a 'lower-level' of the collaboration but is still required in order to ensure that the business interactions- such the order or expected interactions, the type of messages etc, are declared ahead of the process being enacted.

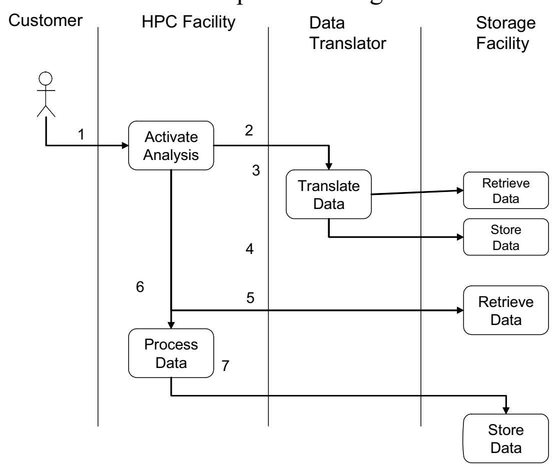

Figure 5. A collaborative business process involving the HPC, Data Translator and Storage services

The technologies described above will be assessed for their benefits in meeting business requirements (both functional and non-functional) and improving business performance. For example, all of the systems described here should be easy to administer and provide greater reach to the administrator, thereby automating repetitive tasks and eliminating redundancy. Business performance improvements are difficult to quantify and assess, but where possible we shall try to compare current procedures (such as those involved with the registration and management of individuals within a PKI based security system, monitoring of service performance, service configuration and administration and so on) with the simplified procedures associated arising from the use of TrustCoM technologies.

5. Conclusion

The CE scenario indicates that the TrustCoM environment could benefit engineering collaborations in different ways. First of all, it leads to an improvement in the modelling and design of the collaboration at the process and agreement level, leading to clearly defined business roles and responsibilities defined by agreements. This potentially enables a small group of top-level business policy makers to design a collaboration that can be fulfilled by the many potential service providers that are accessible via an Enterprise Network. This collaboration can then be enacted by these service providers who are discovered by the VO management subsystem and whose membership is regulated by an agreement defined by the VO designers. The ultimate goal is to introduce automation into the collaboration wherever possible, ensuring that IT systems can be connected together in adaptable ways (as in the case of the federated security) and combine different points of view on the collaboration, such as legal specialists, into the agreement that binds the VO together. From the viewpoint of the service provider, using TrustCoM enables his services to be used within many different types of collaboration with only minimal administration overheads.

The project is currently in the final development and testing phases and will commence an industrial demonstration phase next year. Therefore, the results should be regarded as in their preliminary state and indicative of how the technologies from TrustCoM could be applied to collaborative engineering in service based economies.

Acknowledgements

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A New Collaborative Working Environment for Concurrent Engineering in Manufacturing Industry

Dr. Dragan Stokic
ATB – Institute for Applied System Technology Bremen GmbH

Abstract: The paper addresses the problems of collaboration of teams in manufacturing industry in the scope of concurrent engineering (CE) processes. The problem of involving shop-floor teams in product/process improvements is specifically addressed. The objective is to develop a new information technology platform based on software collaborative services supporting different CE processes where different teams – product design, maintenance, shop-floor teams etc. - around the complex assembly and manufacturing lines have to be involved. The platform is one of the first attempts to apply Collaborative Reference Architecture to support CE in manufacturing industry. The work presented addresses a development of new tools and the core collaborative services for design of such a platform. Several current applications of such platform are indicated.

Keywords: Information systems in CE, CE design, manufacturing and services, Collaborative engineering, Knowledge management in CE, Collaborative services

Introduction

The modern approaches in concurrent engineering (CE) of products/processes in manufacturing industry require involvement of many different teams. The increasing trend of globalised manufacturing environments and a radical increase in number of product variants in modern manufacturing industry (e.g. Build-to-order) requires new forms of collaboration among teams involved in product/process development life cycle, e.g. design, planning, production scheduling, manufacturing, after sales services etc., as well as seamless knowledge and experience sharing among and between these teams, often distributed geographically and in time. This is especially a challenge for manufacturing industry in EU facing massive migration of manufacturing facilities towards Eastern European and Asian countries.

The paper explores how modern Information and Communication Technology (ICT) solutions for collaborative work, so called Collaborative Working Environments (CWE) may support CE in manufacturing industry. The objective is to develop a new collaborative working platform to support collaboration among teams in manufacturing industry allowing more effective CE processes on design/improvement/reengineering of assembly and manufacturing systems (AMS).

The paper is organised in the following way: Section 1 includes a brief overview of the state-of-the art on collaborative work and CWE in manufacturing industry, Section 2 explains the rational and objectives of the work presented., Section 3

elaborates in detail the proposed approach for development of a new platform, while Section 4 provides description of the selected architecture of the new collaboration platform. Section 5 presents some potential applications of the proposed platform, while in Section 6 conclusions and future work are briefly discussed.

1. Collaborative Working Environments in Manufacturing Industry

As indicated above, the collaborative work in manufacturing industry requires solving several fundamental problems. Especially collaboration amongst shop-floor teams and teams in other areas in an enterprise (often geographically dislocated) within CE processes, is currently burdened with a number of problems concerning distribution of work, synchronisation and persistence of workspaces, knowledge activation etc. The problem is the teams in modern and highly flexible manufacturing industry require often different collaboration patterns (e.g. a combination of synchronous and asynchronous collaboration during CE processes). For example, collaboration for decision-making purposes within CE processes has to integrate effective information sharing and activity synchronization [1].

The collaboration amongst teams is still frequently managed using insufficiently systematic methodologies, or following non-human centred manufacturing concepts applied in classical mass manufacturing. This specifically may constrain productivity, collective creativity and collaborative work on innovation.

The application of CWE in manufacturing industry, specifically for collaborative engineering, has been subject of many research activities [2-4]. Different algorithms for e.g. collaborative computer-aided design [4] and various ICT tools to support collaborative work [2, 3] were proposed. Besides generic tools for collaboration (e-mails, “blogs and wikis”), widely applied in different communities, specific solutions for manufacturing industry have been also developed. However, collaboration among teams with different technical backgrounds and with different collaboration patterns (e.g. shop-floor teams and design teams) has not been sufficiently explored, and ICT solutions supporting such collaboration are generally missing. The existing tools do not support dynamically changing collaboration patterns, which is one of the key requirements for effective CE processes in manufacturing industry.

2. Objective of the collaborative platform

Collaboration@Work is collaboration among individuals engaged in a common task to achieve a shared objective using collaboration technologies [5, 6]. CWE aims at improving human abilities to work collaboratively, thereby increasing creativity, which, in turn, will boost innovation and productivity as well as support new value creation forms. Since the 90's, there has been an improvement in Business Processes automation and interoperability, as well as in methods of work for people working alone. Although the work in these areas is far from ended, there is a consensus that it is a time to move the focus towards the improvement of the way in which people work together, i.e. to research and develop new working environments ready for collaboration. They should be developed in line with the new ICT trends, the so-called third wave of Internet, i.e. utility-like network, sensors and wireless technologies, and commodity-like software

[7]. The paper presents an attempt to develop such CWE for manufacturing industry, following this generally accepted strategy.

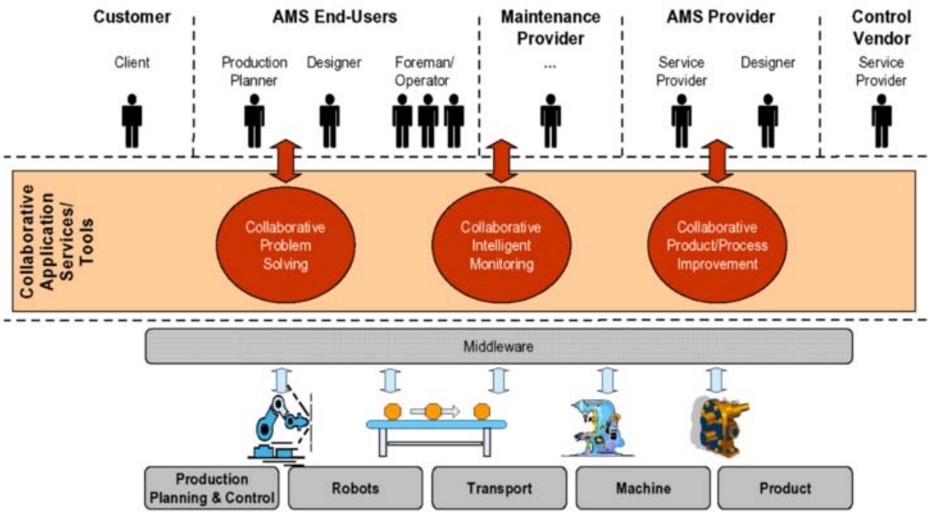

Fig. 1: Targeted solutions: collaborative application services

The objective of the work presented in this paper is to develop generic and widely applicable, modular collaborative platform to support CE. The targeted solution for the manufacturing industry is presented in Fig. 1. The platform will provide various Collaborative Application Services to support CE in manufacturing industry, especially those enabling the teams in shop-floor to be involved in CE processes, e.g. for (re)engineering of AMS. The targeted platform will be open for various services to support CE and to involvement of different actors (AMS designers and service providers, maintenance providers, shop-floor operators, control vendors, including end-customers).

Under Collaborative Application Services are, therefore, understood the services which involve collaboration of different actors, teams, and artefacts within an extended enterprise (EE), and which are focused on specific application areas allowing effective involvement of the teams in CE (i.e. product/process improvements, monitoring of products/processes, problem solving etc.) [8]. These services use the information middleware which provides information on products/process/production units needed for collaborative work within specific application area.

The objective is to develop means/tools to efficiently generate different application services for collaboration among groups in an EE – see Fig. 2 [9].

3. Definition of Main Design Tools

The main design tools are intended to support development of Collaborative Application Services which can be easily integrated in different environments (i.e. at different information middleware, with different legacy systems) and which can be easily integrated with the existing solutions in the application areas (e.g. with the existing solutions for CE, CAD/CAM systems etc.). The design tools include:

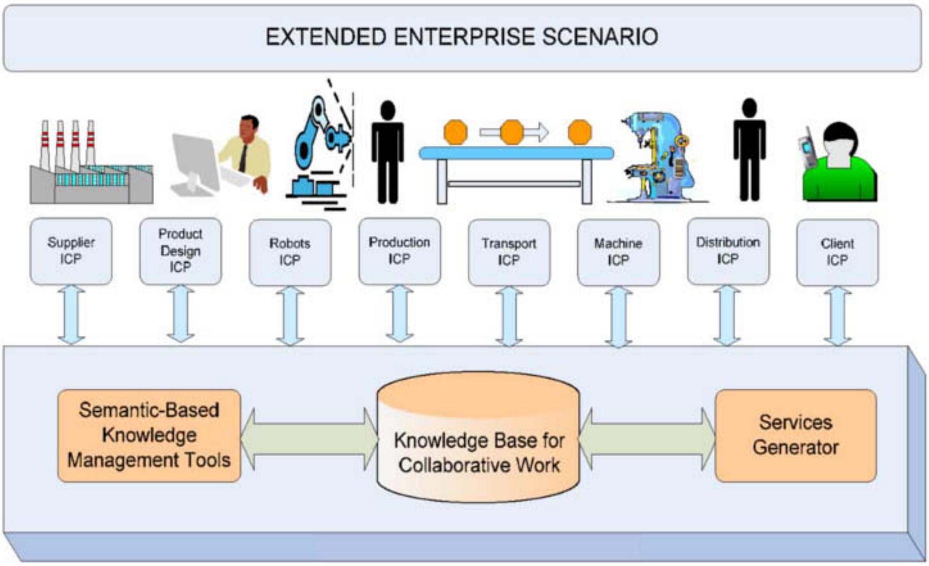

Fig. 2: Design tools

a) **Service Generator**: the purpose of the Collaborative Service Generator is to support the designer/developer to design a new Collaborative Application Service or to update the existing one. The Service Generator includes 2 main sets:

- Tool set to support design of the Application Services and
- Set of Core Collaborative Services (CCS) which can be combined to develop various Collaborative Application Services, identified as common requirements for different application services (see Section 3)

The Service Generator should support a combination of the (new) CCS with existing services. The set of design tools includes several tools. Two key tools are:

- Tool for creation and editing of Application Services (creates the application service by defining its basic structure)
- Tool for identification of knowledge flow for the Application Services (provides a list of available information/knowledge objects and set of available tools for the management of knowledge on problems addressed and allows a designer to select the knowledge objects and knowledge management tools needed for the collaborative work of teams)

b) **Repository** combining information and knowledge gathered along different production-cycle phases over the EE (both system vendor and end-users) with a universal interface to share the information in a distributed, collaborative working environment.

c) **Semantic based Knowledge Management (SBKM) tools** as a basis for collaborative services (e.g. tools to support decision-making, sharing of knowledge within an EE, ontology, tools for personalised and team oriented knowledge presentation etc.) [10].

Therefore, as presented in Fig. 3, the design tools will serve to effectively develop collaborative application services for different teams in an EE, fitting the assumed target architecture. The tools should allow to develop the services supporting CE processes easy applicable in different infrastructures within manufacturing EE [11].

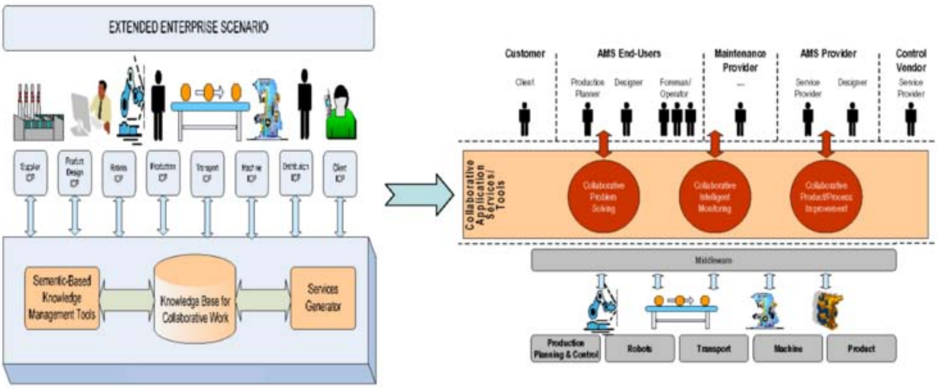

Fig. 3: Relation between design tools and the targeted solutions

4. Targeted Collaborative Architecture to Support CE

Targeted architecture to support CE within an EE is presented in Fig. 4. It represents further elaboration of the initial architecture presented in Fig. 1. The proposed target architecture fits with the proposed Reference Architecture for CWE [12]. It includes several layers:

a) Information middleware which includes interfaces to AMS and other systems to collect information on AMS, products, process needed for collaborative services and CE.

b) CCS – generic set of services supporting collaboration among teams in an EE, which includes: resource discovery (e.g. discovery of the experts within an EE available for solving the current problems, available for either asynchronous or synchronous collaboration etc.), team composition (adjustable to different collaboration patterns), collaboration call, collaboration start-up, product/process knowledge provision (taking into account different expertise of the teams involved in collaboration), collaboration traceability (easy adjustable to different specific needs/constraints in an EE) etc. These CCS will be combined with different communication services (e.g. chats etc.).

c) Service orchestration layer which serves to combine different CCS with different application tools for CE (e.g. design tools etc.). This layer provides the end-user functionalities and synergic combination of CCS (allowing for different collaboration patterns). The 'uniforming' sub-layer assures harmonization and management of CCS.

d) Application service layer which includes set of services to directly support teams in their CE activities (e.g. in simultaneous solving of problems of AMS, product/process reengineering related to the identified problems and needed improvements, etc.).

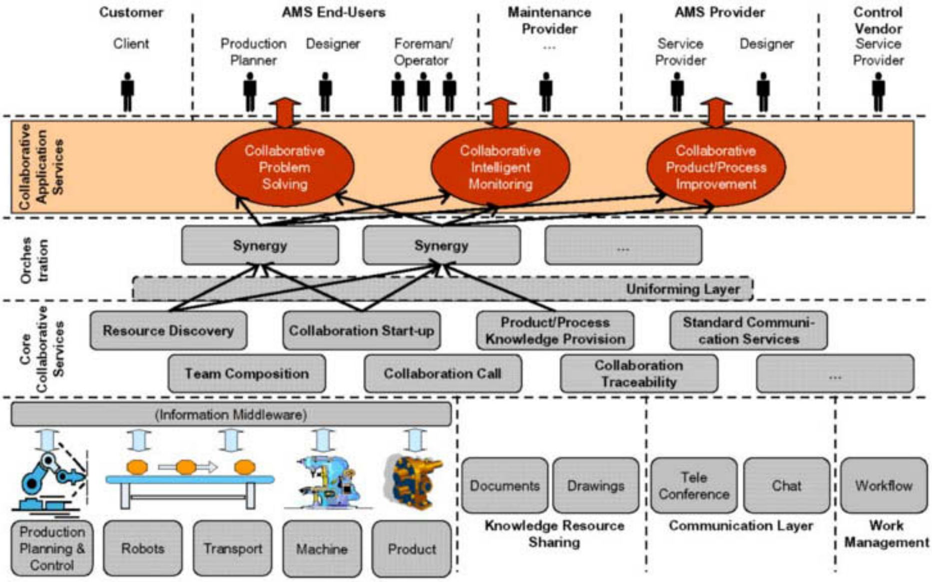

Fig. 4: Target Architecture

The presented architecture will be implemented as a service oriented architecture, allowing for full flexibility and effective instantiation for different CE processes. The key issue is that the design tools and the CCS support different patterns for collaboration among the teams: asynchronous, synchronous, multi-synchronous etc. [13]. For example, CCS for team composition and resource discovery will allow for an easy switching from one pattern to another (e.g. from synchronous work to asynchronous work etc.), which is specifically important for the shop-floor teams. Since the platform (CCS) will support an effective combination of different collaboration patterns it is expected that the involvement of all teams will become more efficient.

The work on CCS will be based on the state-of-the-art research regarding collaboration patterns and collaborative work in general. For example, the development of the CCS for traceability of collaborative work will strongly take into account research on traceability of project development and knowledge modelling [14]. The current research on ontology issues will be also of a high relevance for the development of both CCS and orchestration layer [15]. The special attention will be given to security and Intellectual Property Right issues, being one of the most critical aspects of collaborative work on EE in manufacturing industry [16].

5. Applications and Testing of CWE

The tools for development of the collaborative application services and the targeted architecture will be applied in several manufacturing companies in EE environments to support CE [9].

One of the applications addresses CE of complex assembly lines (for assembling small motors at the automotive industry supplier). The target platform will be applied to support collaboration among the designers of the complex assembly system with

operators/foreman at the shop-floor at the AMS end-user (automotive industry supplier) in order to identify the problems/possible improvements of the line and by this support design of new/reengineered lines. The collaboration will also include maintenance services provider team at the shop-floor, as well as service team at the AMS provider and team(s) at the provider of the control system of AMS. The CCS provided are combined with the CE design and maintenance tools currently used by the AMS vendor. The platform will be used to support collaborative elaboration of the proposed changes in the design of AMS. The currently used platform for collaboration (based on the Siemens' platform ePS [17]) will be upgraded with the CCS allowing for more effective collaboration among the teams in shop-floor and design.

The second application is at a special machine tool builder who develops high productivity solutions for the automotive industry and offers its experience and technical knowledge to the definition of the most suitable solution, depending on the production that can be reached, process to be performed, tolerances, types of pieces and other technical data. The company will use the presented platform for re-engineering of its products and the services offered with these products, mainly in their transfer lines. The platform serves to support the collaboration with their customers. The aim on long term is to involve both product design team and shop floor team at the AMS end user site in the process of reengineering of the transfer lines.

The both applications will serve for testing and validation of the new CWE. The three above listed collaborative application services will be developed and compared with the current practices in collaboration: The criteria for comparison will include efficiency of collaborative work, security and reliability of the new CWE, acceptance of the CWE by employees, motivation of actors involved etc.

6. Conclusions and Future Work

The paper presents the RTD approach in development of a new collaborative platform to support CE work on AMS design/reengineering which includes collaboration of different teams in manufacturing industry. The key innovative aspects of the proposed solution are:

- a combination of innovative collaborative services with 'classical' CE tools
- new collaborative platform fitting with the Collaboration Reference Architecture, being one of the first implementation of this architecture in manufacturing industry
- a set of design tools and CCS for an efficient development of the application services to support CE
- solutions which support different collaboration patterns and different technical background of the collaborating people and by this allow for much more effective involvement of different teams (and specifically shop-floor teams) in CE processes.

The design tools and the targeted platform are currently under development. The first testing with a certain limited numbers of CCS indicate that a very effective support of collaborative work among the teams involved in (re-)design and usage of AMS can be provided by the targeted solution.

Acknowledgement

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A Distributed Architecture for Collaborative Design

Moisés DUTRA, Kamel SLIMANI, Parisa GHODOUS
LIRIS – Laboratory of Computer Graphics, Images and Information Systems
University of Lyon 1, France
{mdutra, kslimani, ghodous}@bat710.univ-lyon1.fr

Abstract. Due to current trends in the design field towards virtual teams that collaborate over computer networks to achieve global optima in design, there is an increasing need for design teams to share knowledge and to establish and maintain a cooperative work through effective communication, coordination and collaboration at the knowledge level. As problems become more complex, teamwork is becoming increasingly important. This paper proposes a web-based multi-agent architecture to support multidisciplinary design teams that collaborate in a distributed design environment. Using ontologies and multi-agent system, the proposed framework addresses communication problem at knowledge level and aims to optimize constraints and conflicts management in concurrent engineering environment. A prototype, based on the Function-Behavior-Structure design framework, was built up to validate this approach.

Keywords: Collaborative Work, Distributed Artificial Intelligence, Knowledge Management, Conflict Resolution

Introduction

Today's complex design projects require teams of designers to come together in order to facilitate the sharing of their respective expertise in order to produce effective design solutions. As the engineering world adopts methods such as concurrent engineering and total quality management, designers are being required to collaborate between them and with customers, marketing people, manufacturing engineers, suppliers, distributors, and all other stakeholders that are likely to be affected by the evolving design process (Domeshek, 1993). One immediate benefit of this kind of collaborative work is the coming together of participants with heterogeneous skills (Edmonds and al., 1994), who, on sharing their knowledge, skills, expertise and insight, create what is known as distributed cognition (Hollan and al., 2000). The collaboration of individuals with different insights, tacit knowledge and expertise generally results in the generation of new insights, new ideas and new artifacts. Basically, someone viewing the problem from an alternative perspective can help in uncovering tacit aspects of a problem previously hidden. Collaborative designs generally result in work products which are enriched by the multiple expertise and skills of the designers engaged in the design task. For this, cooperative multidisciplinary design teams dispersed across the enterprise have to be supported and, the management of distributed information and knowledge has to be facilitated within what is known as a distributed design environment (DDE). However, despite the advantages and desirability of distributed design, current DDE models fall short of providing an effective solution to distributed cognition and

effective knowledge sharing and collaboration on design projects, because they fail to support the geographical, temporal, and functional dispersion of human knowledge and information that is required during the collaboration process between distributed individuals in a virtual environment.

This paper addresses this problem by describing the proposition of a Web-based multi-agent system architecture for collaborative design, with emphasis on the "cognitive synchronization" concept (Darses, 2004) (Ruiz-Dominguez and Boujut, 2004) and "rational design" for building a shared point of view and thus reach a "satisfying" solution (i.e. that meet the problem specification). In the next sections will be presented the architecture of a Web-based multi-agent system for collaborative design and showed how effective collaboration and knowledge sharing are supported through coordination, cooperation and cognitive synchronization. It will be also presented a prototype to valuate a case study.

1. Overall approach and System Architecture

The proposed engineering design system can be viewed as a network of computers and users (Slimani and al., 2004). The system is organized as a population of asynchronous and autonomous agencies for integrating engineering tools and human specialists, within an open environment (Figure 1).

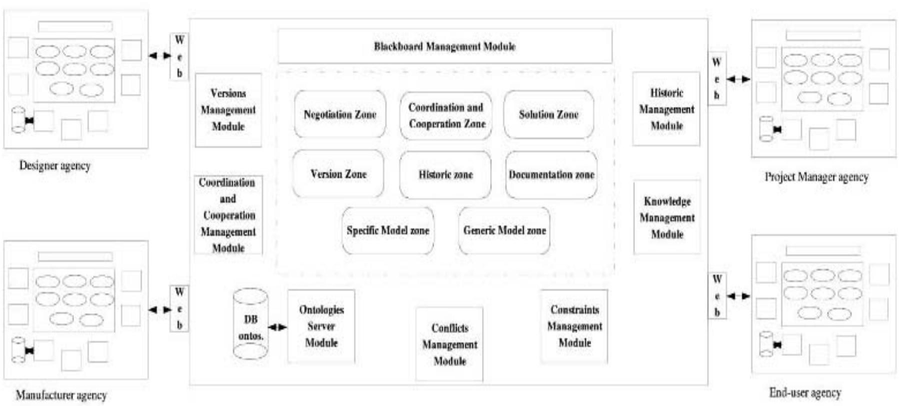

Figure 1 – Architecture of the Collaborative Design System.

An agency is a web-based multi-agents system for which each agent represents the activity held in a design discipline. The use of agencies allows for the restitution of a global view, to a given participant (customer, designer, etc.), whereas agents in a given agency, represent disciplines taken into account for a given participant. Each tool (or interface for human specialists) can be encapsulated as an agent in a particular agency. The approach for large engineering projects is to decompose the overall task of designing, a complex artifact, into a set of different services. Such services are used by local teams (represented by agencies) which, in turn, communicate with other teams.

In an agency, as well as at the global architecture level, engineering tools and human specialists are connected by both a network (local network and internet) and a blackboard (a shared workspace/global distributed technical database). They communicate (exchange data/information, cooperate and coordinate their activities) via this network and shared global workspace.

2. Web services-based system

The system for collaborative design proposed is composed of several data spaces and active modules and it is Web-services-oriented. Indeed, each module of the system (which can be one or more agents) offers services that the other agents (other modules of the system or agent interfaces representing human specialists) can require. The system stores the services offered by the various modules (providers or service suppliers) in a directory, that other agents – costumers or clients – can solicit (Figure. 2). For example, a designer can solicit the service of constraint verification to check the consistency of constraints related to data he handles. Moreover, the Constraints Management Module can request the Conflicts Management Module in order to launch a procedure of resolution of conflict if a constraint is violated.

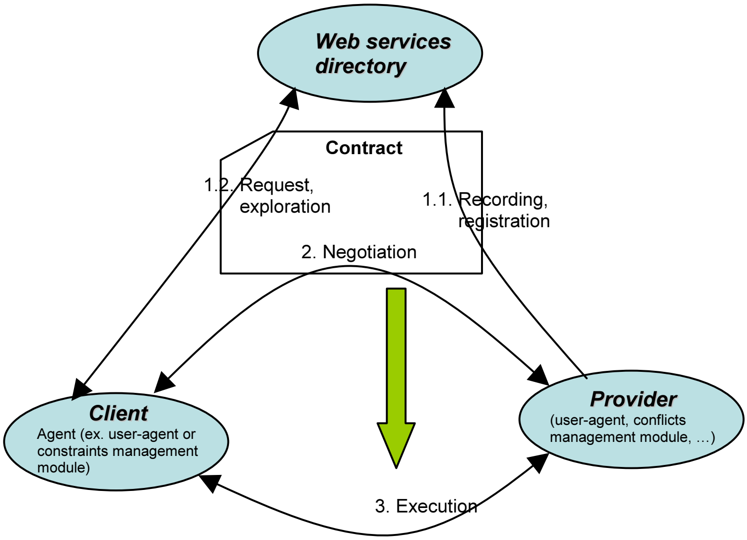

Figure 2 – Web services oriented system

3. Communication as support for cooperation and coordination

Cooperation and coordination rely on communication protocols that can be verbal and natural – or computerized – and they represent a big issue in multi-agents based CE systems. Communication enables agents to exchange information and to coordinate their activities. When the communication is inadequate, some agents fail to have sufficient communication necessary for coordinating their designs for a period of time, or keep on ignoring the other agents' requests and/or the design changes, and this lack of communication and coordination carries out conflicts.

In cooperative design systems, we distinguish in the literature between two types of communication: systems using the message-passing approach and systems based on global shared workspace (data repository). This work is particularly focused on very large design projects in various domains, such as, automotive and aerospace industries. Such design projects share the following characteristics: the design requires a large number of individual designers or several working groups to work together, the design period is long, and the design is very expensive. In this case, it is not considered that neither a message passing nor shared data repository based system taken only is well suitable for an efficient collaborative design. This system combines both of these approaches, allowing efficient/better communication and cooperation in the collaborative design process. According to the nature of the information and data to be treated, this information can be saved in the shared workspace for requesting or modifications, or be exchanged between agents to answer a precise need (conversation, negotiation, etc.).

4. Constraints and Conflicts management modules

The role of constraints management module is to guarantee the consistence of manipulated data. It verifies that constraints fixed by user and designer agencies are valid. For this purpose, the module groups the constraints furnished by the different experts according to the physical parameter it deals with. For each of these parameters, it tests if there is a contradiction between the related constraints. If there is one, the resolution of this problem is transmitted to the conflicts management module.

The constraints management module estimates at every new state of the design process, the constraints and verifies if these last ones are verified or not. In the negative case, this module notifies to the conflicts management module, the violated constraints (Figure. 3).

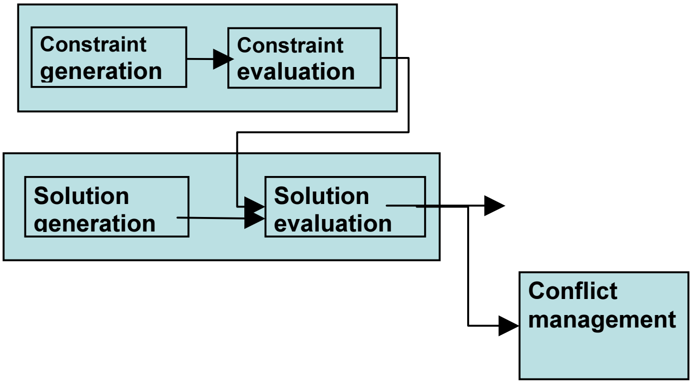

Figure 3 – Constraints management and conflicts management coordination process

Thanks to the cooperation and coordination zone and to the system log, the message sent by the constraints management module to the module of conflicts management, contains the identification of the violated constraint, the resources which it concerns, and the concerned experts. From there, the conflicts management module (Slimani and al., 2006), augments this message with other significant information in relation to the type of conflict in question, and then notifies the concerned experts. If

the conflicts management module cannot determine in an automatic way, a solution for the conflict by management of priorities – or by extracting an existing solution from the case base containing the former conflicts and the solutions which were proposed to solve them – then, a negotiation, supported by the various modes of communication, is initiated among the concerned experts.

5. Prototype

A prototype has been built up in order to validate the proposed architecture. Providing a computational environment, it intends to be an infrastructure tool through which several experts can collaborate in order to achieve a product design. Collaboration in this context comprises interaction among different knowledge areas. In an effective and collaborative environment, experts came from different areas can integrate their knowledge in a simultaneous way, looking for an expressive gain of productivity. In spite of being interesting, that approach demands firstly the tackling of some problems, such as: specification and requirement formalization, integration of different ontologies, detection and resolution of conflicts.

Experts have their own way to see and to understand the subject, according to their duties. Therefore, this architecture must provide mechanisms of data representation so that a common result can arise from the interaction among experts' different ontologies. Once this data representation is defined, it will act as a "common language" to all system actors. From this moment on, they can "understand" each other. When this scenario is running, it will be possible to detect specification conflicts.

Specifying and formalizing knowledge (especially that one expressed in natural language) demands a great effort towards obtaining representation patterns to aggregate several disjoint knowledge areas. Each expert should express himself so that the others can understand his information correctly. It is necessary, therefore, the using of a flexible and sufficiently extensive representation language of data to accomplish such a task. This language will also be used for the exchange of information between the experts and their respective ontologies. Once this representation is defined, it is then required the creation of mechanisms to look for incorrect and conflicting information. As soon as such scenario is set up, it is necessary to settle an approach for the conflict resolution like, for example, negotiation. In this approach, the environment itself is in charge of notifying the interested parts of existing conflicts. These parts, then, begin an exchange of messages, interacting to reach a satisfactory solution for everyone.

The prototype is based on John Gero's Function-Behavior-Structure design framework (Gero, 2000). According to this framework, a product structure is obtained starting from function and behavior models related to the product. Every structure model is derived from one or more behavior models. Behaviors are derived from function models and every function will be defined from one or more formal product specifications. Hence, as these models are interrelated, one of the main goals here is to formalize product requirements, turning them into formal specifications.

Other prototype's objectives are:

- Simulate the interaction among different experts inside a collaborative design project;
- Work as a support architecture to concurrent engineering, representing several types of knowledge;

- Provide ontology integration in a synchronous environment;
- Detect and resolve the conflicts arose from this process.

The prototype's internal structure comprises three roles: system administrator; specialists, called agents; and specialist groups, called agencies. The system administrator is the project manager. He is in charge of project creation, definition of objectives, date delimitation, attribution and management of agents and agencies (Figure 4). Attributions given to agents and agencies include right access and system using access. Moreover, the administrator defines to each project the final product, as well as the actors who will take part of it.

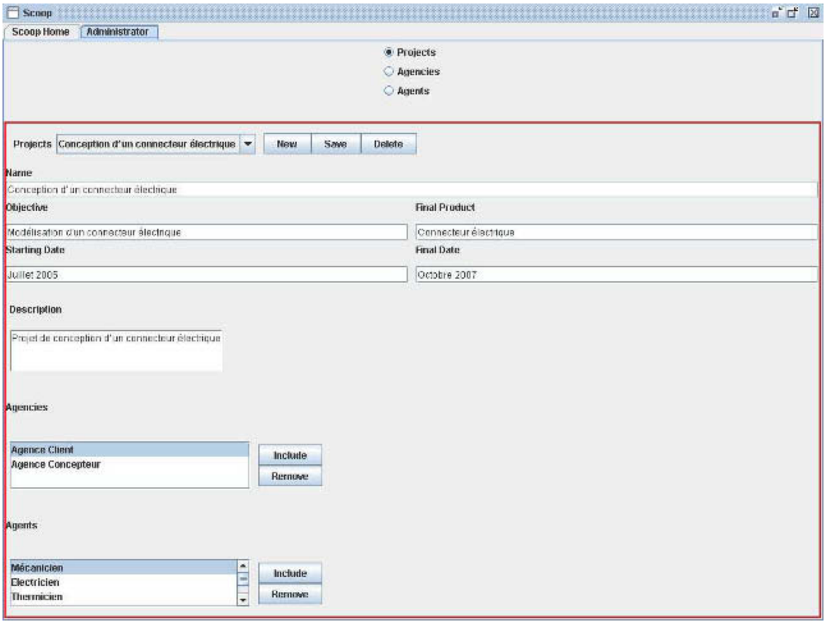

Figure 4 – Project Management

Actors are agents (experts) and agencies (expert groups) which are involved in the product design. The agents get registered in the system their occupation, specialty, interest areas, company, contact data (address, e-mail, phone number, etc.). Besides, each agent has an identifier and a password for system access. This access will be enabled by the system administrator, through the right management policy.

An electrical connector design, as depicted in Ghodous (2002), was chosen as scenario to this prototype. There are two participating agencies taking part in this project: Client Agency and Design Agency. And also, four agents: Costumer, Mechanical Engineer, Electrical Engineer and Thermal Engineer. An agency is an agent group organized according to a technical criterion, a knowledge area or a specialty. An agency can comprise: clients (people or companies); engineers (thermal ones, mechanical ones, electrical ones, etc.); marketing department; sell department; human resource department; administration department; among others.

Agencies must be the link among experts who share the same points of view in product design or those whose knowledge is similar. Because of it, they can interact in a better way in order to achieve a common opinion. Thus, it has been settled the Agency Shared Workspace (ASW). The ASW is a blackboard built up to provide intra-agency interaction. Inside it can be found four models, based on FBS design

framework: Specification model, Function model, Behavior model and Structure model. These models will be the base for the product design according to the agency point of view. Specifications are formalizations of client requirements, defined in the data representation language OWL (2006). Each function takes as starting point one of these specifications. Specifications can be better detailed if they are defined by an agency exclusively designated to this purpose, e.g., a Client Agency. Otherwise, transforming product specifications into a final structure becomes better if made by a skillful agency, like a Design Client.

The agent has his own workspace, the Agent Private Workspace. In there, he does his job detailing it according to his specialty. The information is organized in a tree; making clear the inheritance of leafs. E.g., for a given structure, a related behavior is required. Figure 5 shows in details a structure ("*Container*") defined by the agent "Mechanical".

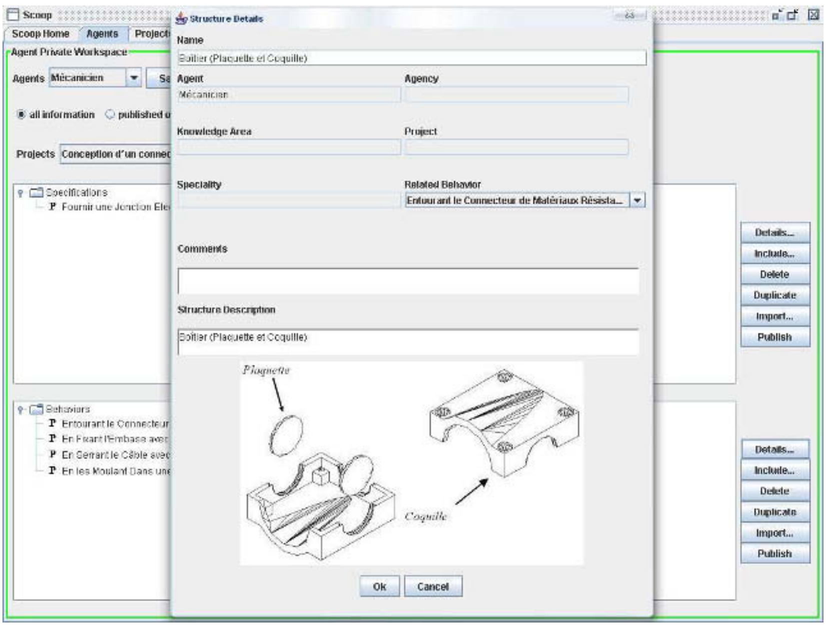

Figure 5 – Agent Private Workspace – Structure Details

So, each agent keeps his own view of data. In his private workspace, the information is structured according to his competence. In there, he is able to modify whatever he wants. It is also possible for him to import information from other agents, in order to improve it or to aggregate it inside his schema. When the agent thinks that some leaf should be shared in the agency scope, he publishes it in the Agency Shared Workspace. Once this is done, all members of the agency will be able to see and to make changes to these shared data.

Once the ASW data are consistent, they are transferred to the Project Shared Workspace (PSW). The PSW is a great blackboard whose access is available to every actor in the system, the global version of ASWs. When the information arrives to PSW, it can be accessed and handled by all participants in the project. In this point, the collaboration becomes actually global.

The same proceedings of data sending will be expected to be carried out by all agents, from their private workspaces towards the ASWs, and from ASWs toward the PSW. Intra-agency integrity problems and data conflicts are treated in the scope of ASWs. Inter-agency problems and conflicts are treated in the PSW. The composing structures defined in the PSW are, hence, the final structures of product design.

6. Conclusion and Perspectives

This paper presents a Web-based multi-agent system architecture for collaborative design. The main features of this system are: a Web Services Oriented Architecture; the use of the "agency" concept; a hybrid multi-agent organization (autonomous agents approach and federation approach); a hybrid mode of communication (direct/indirect and synchronous/asynchronous); the use of ontologies to share/exchange knowledge and information; an open and domain independent system. Knowledge management in design is becoming an important area of research. The challenge here is to capture and re-use the existing designs and knowledge which they generate, by using and combining several techniques from knowledge representation domain such as reasoning and using semantic resources, in order to propose a help and to adapt to the various conditions and constraints for future projects.

Improve Graphic User Interfaces of access to the system and management of users' profile in order to propose interfaces best adapted to users' need represents another perspective. Finally, given the big volume of data and information which circulate in the system, it also is important to optimize the algorithms of information management existent in the system.

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WiPam – Wireless Patient Management, a Novel Telemedicine Solution

Freddy REYSKENS [a]
[a] *RDSM nv, Belgium*

Abstract. Telemedicine is a promising field in medicine and many studies show the importance on patient's health and cost saving. The company RDSM has found a cheap, wireless and completely automated solution for following up patients in the comfort of their homes.

Keywords. WiPaM, telemedicine, e-health, telehomecare

Introduction

Although telemedicine is considered to be a fairly new discipline in medicine, the inventor of the ECG, Einthoven, already found a way to transmit ECG data from the hospital to his lab using telephone wires in 1906!

According to the online encyclopedia Wikipedia [1]: "Telemedicine is composed of the Greek word τελε (tele) meaning 'far', and medicine. It is therefore the delivery of medicine at a distance. A more extensive definition is that it is the use of modern telecommunication and information technologies for the provision of clinical care to individuals located at a distance and to the transmission of information to provide that care."

Telemedicine can roughly be divided in three domains:

- telehomecare: follow-up of patients that have been diagnosed with a (chronic) disease, in order to detect exacerbations
- teleconsultation: a physician will try to make a diagnosis from a distance, using equipment in the 'telemedicine station'
- telesurgery: a surgeon can perform surgery in a distant location through a robot that he can manipulate

Since recently many governments, health care institutions and commercial companies have been actively looking for into the field of telemedicine as a whole and telehomecare in particular. The reason for this is that many studies show the interest of telehomecare of patients. These studies show that telecare reduces costs and improves overall health of patients.

The Belgian company RDSM has developed an innovative way for follow-up of patients using wireless transmission of physiological data.

1. Importance of Telemedicine

Many studies have shown that telehomecare improves follow-up and overall health in patients with chronic disease and cuts healthcare costs significantly. The most important chronic diseases are asthma, COPD, hypertension and diabetes.

1.1. Telemedicine in chronic respiratory illness

One Israelian study [2] showed that home monitoring of asthmatic patients with the telespirometry system may improve the management of the disease and the quality of life and reduce costly hospitalizations.

In a three month pilot study [3] of a home monitoring service for patients with chronic obstructive pulmonary disease, fifty five patients were recruited. They transmitted physiological data to a monitoring centre once a day. There was evidence of a substantial (approximately 50%) decrease in rates of hospital admission. The service was highly acceptable to the patients.

In a Japanese trial [4] patients with a high risk for hospitalization were screened based on the numbers of emergency room visits and hospitalizations found in a previous study and randomly assigned to either the telemedicine or control group. After a six month study period, an 83% reduction in hospitalization was demonstrated in the telemedicine group versus the control group, with a P value of 0.01. Improvement of peak expiratory flow and symptoms were also shown in the study group.

An Italian study [9] showed that telemonitoring of patients with severe respiratory illness decreased the numbers of hospital admissions and of acute home exacerbations by 50% and 55%, respectively, cutting hospitalization costs by nearly 17%.

1.2. Telehomecare in Diabetes

Biermann *et al.* [5] found that telemanagement of insulin-requiring diabetic patients is a cost and time saving procedure for the patients and results in metabolic control comparable to conventional outpatient management.

Dubault *et al.* [7] calculated that the state of Florida could have realized a net potential savings of $89,590.22 over three years using telehealth in diabetic children.

1.3. Hypertension

Homecare blood pressure monitoring using automated transmission of data can also improves diagnosis of essential hypertension compared with usual care. In a trial by Rogers *et al.* [8] 64% of patients with essential hypertension were diagnosed in the telemedicine group; in the usual care group, 26% of patients with essential hypertension were diagnosed.

1.4. Other

A geriatric telemedicine trial in Hong Kong [6] showed telemedicine was adequate for patient care in 60-99% of cases in seven different disciplines. The CGAT was able to serve more patients and see them earlier and more frequently. Telemedicine was cheaper than conventional care, and well accepted by health-care professionals as well as patients. Substantial savings were achieved in the study period through a 9% reduction in visits to the hospital emergency department and 11% fewer hospital bed-days. Telemedicine was a feasible means of care delivery to a nursing home and resulted in enhanced productivity and cost-savings.

A study evaluated patients' cost savings in a telehealth project at the University of Arkansas for Medical Sciences' (UAMS) during 1998-2002 [10]. Results suggest that without telemedicine, 94% of patients would travel greater than 70 miles for medical care; 84% would miss one day of work; and 74% would spend $75-$150 for additional family expenses. With telemedicine, 92% of patients saved $32 in fuel costs; 84% saved $100 in wages; and 74% saved $75-$150 in family expenses.

These studies demonstrate the possible cost savings and the improved medical care using telemedicine.

With health care costs rising dramatically, these possible cost savings using telemedicine are very enticing to governments, private insurers and health care professionals.

Therefore the potential market in this field is enormous.

2. WiPaM

The Belgian based company RDSM (*Research, Development and Sales for Medicine*) has developed a novel home-care telemedicine system. The WiPaM system (*Wireless Patient Monitoring*) enables follow-up of patients in their own houses in a wireless and completely automated manner. The system is very cheap compared to other existing solutions and more patient friendly.

RDSM integrates wireless Bluetooth technology in existing medical devices to make them able to send the measured physiological data to a Bluetooth enabled hub.

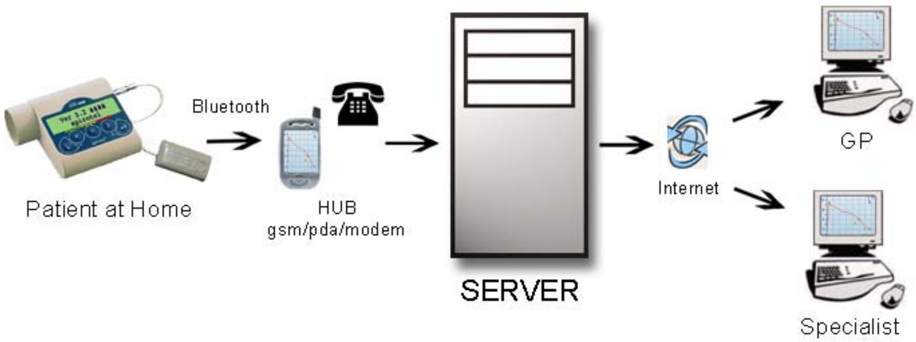

Figure 1: The WiPaM system

2.1. Principle

The WiPaM system is completely automated which eliminates patient's errors and improves compliance. The patient initiates the automated sequence of events by a simple push of a button. The medical homecare device (blood pressure monitor, spirometer, pulse oximeter, blood glucose monitor) will measure the physiological data and automatically send the result to the hub (Figure 1).

This hub can be a standard Bluetooth enabled mobile phone or a Bluetooth enabled modem, and is able to send the data it received to a central server, using standard mobile (GSM) communication or transmission over telephone line.

Results are sent to the secured central WiPaM server.

Test results can be accessed by health care professionals, using a secured login procedure.

A lot of attention has been given to security of the system. Data is always encrypted and sent anonymously. The serial number of the device is sent along with the results and the connection of this serial number with the patient is made in the central server.

The health care professionals are able to program their proper alerts. They will be send a message if test data deviates from the range they enter. Alerts are sent through email, fax or SMS.

2.2. Available devices

At the moment a Bluetooth enabled blood pressure monitor and weight scale are in production and prototypes of a spirometer and pulsoximeter are in preproduction phase. A prototype of a blood sugar monitor is in development.

A wireless ECG device has been linked to the WiPaM platform.

2.3. Ease of use

Many chronically ill patients, especially for COPD, are situated in lower social classes. Many of these patients will not succeed in handling complicated devices. The WiPaM system is optimized for ease of use for the patient, who only presses a button to initiate an automated sequence of events to send the data to the server and the treating physicians.

2.4. WiPaM Network

An expanded version of the WiPaM platform is the WiPaM Network. It enables all treating healthcare professionals to access the data and to add comments and test data done in their offices. Test data from medical devices and lab results can also be sent automatically to the WiPaM server using standard broadband internet connection and included in the patient's medical file (Figure 2).

This network between patients, general practitioners and specialists is advantageous for all people in the network. The patients are assured of a better follow up, while treating staff maintains good communication and can see the test results, diagnosis and treatment of their colleagues.

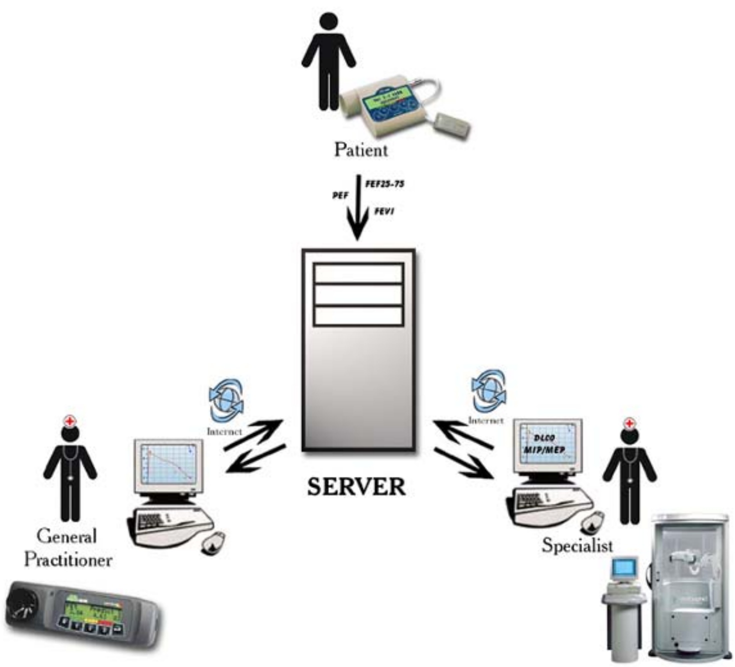

Figure 2: WiPaM network

2.5. SpiroLogistics

The WiPaM platform has also been optimized for clinical trials, with automatic transfer of trial test data to the server. Online questionnaires have also been included for patients to answer.

3. Experience

The WiPaM platform has been used in various pilot studies. One study has been done with patients that received a bone marrow transplant [11]. The system was well accepted by the patients.

A study is being done at the *Charles Nicolle* hospital in Rouen, France where pediatric patients with respiratory disease are being monitored.

A clinical trial has started at the University Hospital of Antwerp, Belgium. Seventy-five pediatric patients with cystic fibrosis will be monitored in order to quantify the outcome on health and total costs of telemedicine.

A similar study has started at the University Hospital of Liege, Belgium for patients with COPD.

A large scale study will start shortly with patients with dementia, Parkinson, Alzheimer or epilepsy at the University of Ghent. The goal of this trial is to prove that in these patients telemedicine will be cost effective.

A clinical trial on sudden death in athletes will start using a wireless ECG device.

In the South of France a trial will start for patients with asthma and COPD.

A trial with 50 COPD patients will start at the University of Maastricht.

4. Conclusion

Many studies have shown that telemedicine produces significant cost savings We believe that use of the WiPaM system can result in significant cost saving and improved health care as has been shown in other studies on telemedicine.

The results of ongoing studies will further quantify the actual cost-savings and influence on patients' health in different pathologies.

At the moment further studies need to be done in order to compare the influence of the WiPaM system with other existing solutions. We believe that the ease of use of the WiPaM system will result in better cost savings compared to other, non-wireless solutions, as fewer patients will need technical assistance with the WiPaM system.

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Supporting Interactive and Collaborative Product Configuration for Internet Commerce

Ruby K.Y. Cheng, Stephen C.F. Chan* & Vincent T.Y. Ng
Department of Computing, Hong Kong Polytechnic University, Hung Hom, Hong Kong
**Email: csschan@comp.polyu.edu.hk*

Abstract: Customers nowadays commonly select product and make purchases on the internet. In the process they often want to make limited changes to the configuration of the product, perhaps in collaboration or consultation with a product support engineer. Currently very few e-commerce applications can provide such flexibility to the customers. This paper describes the design and implementation of such a system. The collaboration agent, Co-assembler, enables casual customers and designers to design and perform configurations of 3D products collaboratively over the internet. Clients using Co-assembler through a Java enabled web browser have been developed using platform independent Java language which can run the application everywhere. A three-tier client-server approach facilitates communication between clients and server.

Key Words: collaborative work, Co-assembler, client/server, PD tree

Introduction

When customers e-shop, being able to obtain accurate views of products on the web is of utmost concern. Beyond that, parameterization allows customers to select optional or alternative features. For example, Nokia [1] uses 3D product demonstrations to display mobile phones of different colors and Toyota [2] displays 3D virtual cars showing different types of wheels and accessories. IKEA [3] allows customers to plan office layouts and then generate 3D models. Varlamis, et al. [4] similarly described an interactive system for designing a room, defining the furniture and placing appliances. ParallelGraphics [5] implemented a 3D interior designer program for recombining a collection of kitchen furniture. IKEA [6], too, have offered parts for building customized furniture.

For various reasons, 3D assembly systems have not yet been widely implemented. Chan et al. [7] suggested that there may be four main barriers to the widespread, efficient implementation of customer-driven, interactive product assembly modeling. Firstly, 3D object manipulation is not a simple, intuitive skill. Secondly, even customers who can successfully use such tools will not necessarily be the best designers. Thirdly, there are currently no standards to record the assembly information. Fourthly, other systems do not provide an interface or functionality suitable for collaborative assembly.

We have designed and implemented Co-assembler, a 3D product assembly system that automates many of its processes, allowing casual customers who are not experts in designing 3D objects to configure pre-defined 3D products relatively easily. To demonstrate the functionalities of Co-assembler, we implement an application scenario of an office furniture store that allows customers to select and design a number of pre-defined furniture. In our previous papers [7, 8], we have described the configuration and architecture of the assembling system. Features like users recommendation helpers, object assembling processes and assembly-specific data formats are also included. In this paper, we focus on the client/server collaboration framework. The technical requirements and problems in implementing a real-time collaboration environment like conflict handling will be discussed. A few sample collaboration scenarios in using our Co-assembler for furniture design will also be demonstrated.

1. Related Work

Collaboration over the internet can be done by either peer-to-peer or client/server networks. In the peer-to-peer approach, each PC acts both as a client (information requestor) and a server (information provider). Every users can communications directly with each other and share the same network resources. The information stored is uniquely decentralized as all the hard disk drives are accessible by all networked-PC. Unlike a peer-to-peer network, a client/server network has a centralized storage disk and the central server can serve simultaneously many clients. The use of a central server can simplify the handling of clients' conflicts in sharing resources.

Shervin et al.'s [9] applet-based telecollaboration system used a network-centric approach to let the clients to run any applications provided by the network without having that application preinstalled on their machines. Thimoty's [10] Webtalk-I and Webtalk-II networked virtual environment discussed a virtual museum for cooperation between multiple users within a three-dimensional representation world. Users communicate through the two networks mentioned above. The frameworks are written in Java, VRML, Java3D, XML and JDBC. Wang et al [11] developed a information communication model for consumers to participate collaboratively in conceptual design. They made use of Java, Java3D and a database management system for the implementation. Xu et al.'s [12] preliminary tool for assembling solid models also implemented using Java, Java3D and a web-based product data management. Jiang et al. [13] described an e-service that incorporated customers, manufacturers and suppliers in manufacturing parts. Their system was built using Java applet-servlet pairs, HTML files, JDBC connections and a web database.

In an earlier paper Chan et al. [14] discussed in detail a real-time collaborative design which described a network infrastructure for supporting real-time collaborative solid modeling (CSM) on the Internet. Co-assembler takes this earlier design approach and features that allow products to be virtually assembled collaboratively in a web-based environment.

2. Support for Collaborative Assembly

Customers wishing to construct a piece of office furniture within our scenario - either alone or collaboratively - would access a client application via the server. They then input choices, preferences and personal (ergonomic) data through the Interactive Interface Layer. This information is passed on to the Assembler Layer which creates the virtual furniture. Within the Assembler Layer, the composer sub-layer controls basic 3D operations such as attachment, sliding, and rotation. The parametric sub-layer coordinates and relates a wide range of features, for example, proportion. Customers can store created objects in the Data File Layer.

2.1. System Framework

In the development of Co-assembler, we use a Java applet embedded in a web page, which can be viewed through web browsers that support Java3D. Since our aim is to allow geographically distributed users (customers and designers) to design a product collaboratively in real-time over the internet, there are some issues incorporated in the development of Co-assembler as described below:

1. Internet support. Users can use Co-assembler application using Java3D enabled web browsers.
2. Platform independent. To allow users using different platforms to collaborative work together, Co-assembler is being developed using Java which can be installed and run on multiple platforms. In addition, both Java and Java3D run-time can be obtained freely on the internet.
3. 3D model. To allow users to visualize the accurate 3-dimensional view of a piece of furniture online is very important for them to experience the use of space in the reality. The use of Java3D allows users to change the view point, rotate, translate and zoom in on an object easily.
4. Access remote resources. Since users need to work collaboratively in real-time, all files are stored in the server side and users can load the files at any time online if they have the right to do so.
5. Concurrency control. To prevent conflict between users in manipulating a shared object, a locking mechanism is used in this system.

Based on these major system requirements, Co-assembler have been developed as discussed in the next section.

2.2. System Architecture

Co-assembler is entirely written in Java [15], and we have made extensive use of Java extensions technology. Among these, we have use Java3D for 3D modeling, Java 3D object loader for loading different file formation like VRML, Object files and LightWave, JAXP for parsing and transforming XML documents, JDBC for central database connection, and Java RMI for remote communication between clients and server. The real-time collaborative system has a 3-tier client/server architecture as shown in Fig 1.

It can be seen that clients connect to the server through Java-enabled web browsers. The clients and the server communicate through Java Remote Method Invocation

(RMI). As a Java applet cannot create and retrieve files on the client side, RMI is used here to handle the creation, retrieval and saving of files by clients on the server. In addition, the RMI server also acts as a bridge for communication between clients. A MySQL database server [16] is applied here to manage the user and project accounts.

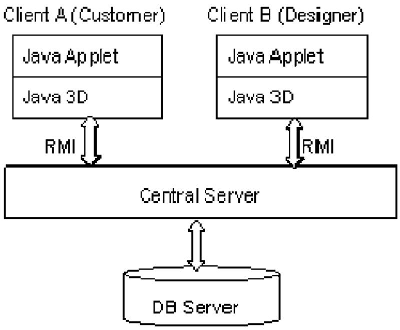

Fig 1. Internet-accessible Co-assembler with Co-assembler server and the client application architecture

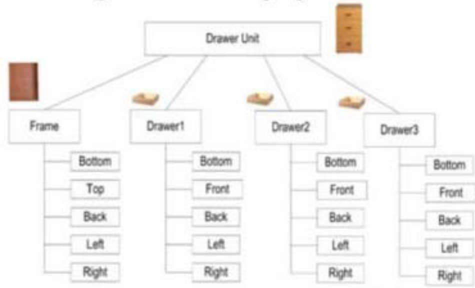

Fig 2. The identification of all primitives of a drawer unit.

Design Action Transfer

In Co-assembler, clients are allowed to establish a collaborative session, in which clients can share the same files and edit the same objects synchronously. One of the essential features in an interactive collaborative environment is to allow clients to update and notify each other any changes on the object in real-time. Certainly Co-assembler has to support this feature.

To support this feature, every action and particularly change made on the 3D canvas need be monitored. When one of the collaborating clients load a file from the central server, all clients committed in this session should be notified of this load-file action. It is similar for other file actions such as saving, deleting and unloading.

The situation become more complicated when clients manipulate the 3D object such as like picking at different surface, changing the shape or color of a specific part of the furniture or orientating the object in different viewing angles. In Java3D scene graph, all objects in the virtual canvas are arranged in a tree-like data structure that maintains the logical and spatial relationships between the objects. In theory, one can send the modified scene graph node, i.e. a branch group of the modified table, to the server and forward to all collaborating clients. However, Java3D scene graph objects are non-serializable and hence cannot be transferred through the network. In addition, the network traffic will be very heavy if we update the scene graph object by transferring the complete scene node over the network.

Because of these reasons, Co-assembler transfers the design action incrementally. It identifies each scene object with an ID. For example, a drawer unit containing three drawers can be named as shows in Fig 2. When a client pick the 'Front' face of Drawer1, the following information about the action will be sent to the server:

1. if the client change the shape of this front face, the following will be sent to the server

- the object picked (Drawer)
- the part picked (Drawer1)
- the face picked ('Front')
- the shape chosen (i.e., round handle)

2. if the client rotate this object, the following will be sent to server
   - the object picked (Drawer)
   - the part picked (Drawer1)
   - the face picked ('Front')
   - the matrix of the rotation made

The information above sent to the server are in primitive data formats such as string and floating point number which are of small data size for transfer in the network.

Concurrency Control

The communication between clients and server is supported by Java RMI. When both clients Ann and Bob want to modify a shared object, say the table legs, at the same time, conflict may occur. In the Java RMI thread controlling mechanism, data sharing can be coordinated by using synchronization method, in which only one thread can execute at any given time, providing mutual exclusion in data sharing.

In our system, the data structure and files are designed and implemented with a tree-like structure called a PD tree [7]. The data structure of the parametric layer in the Co-assembler client architecture is the product data structure. It is used as the basis for sharing and exchanging design information. A primitive is a leaf node in the PD tree while a product and a part can be represented by the intermediate nodes in the PD tree. Each client and server contains a copy of the product model being designed. A design event executed by a client is forwarded to the server. The server recreates the event and broadcasts the event to all other clients. Then, copies of the product model owned by clients are synchronized.

To apply locking to a product, part or primitive node in a PD tree, multiple-component writers (multiple writers overall but single writer only for each component) is supported. For example, Ann and Bob work collaboratively on a cabinet. The PD tree is represented in Fig 3. While Ann is modifying the 'frame' of the cabinet, the corresponding frame node is locked and hence it's sub-parts. At the same time, Bob tries to change the size of the whole cabinet which needs to lock the 'Cabinet' node. This lock request is denied as the intermediate node 'frame' is already being locked by Ann. Bob can only modify the 'shelves' or the 'door' node.

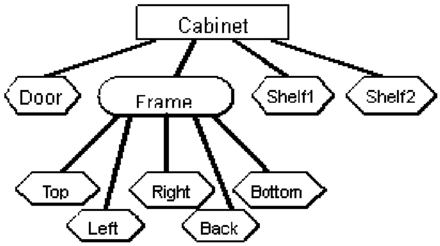

Fig 3. The PD tree of a cabinet

3. Working Examples

In the following scenarios, two clients Ann and Bob share the same project "OfficePlan", containing four set of files as show in Table 1.

Table 1. Files in OfficePlan project

File name	Furniture type
Bookcase	Bookcase with 2 shelves (3 layers)
CabinetLeft	Cabinet of left rotating door with 2 shelves (3 layers)
DrawerUnit	Drawer unit with 3 drawers
Table2P	Table with 2 plane-legs

Case 1

Ann and Bob start a collaboration session. They want to work together on a working desk with a joined drawer unit. The 3D canvas of both clients will be cleared and reset to the original viewing axis. The following steps describe their design actions.

1. Ann loaded a "Table2P" file which contains a table with two plane legs. A request for open file action will be transferred from client Ann to the Server. The content of all the files associated with this object will be sent to Ann. At the same time, this load-action will be captured by the server and the same content will be transferred to Bob.
2. After the conversion of the file contents from XML to Java 3D objects, the table is displayed on the 3D canvas of both clients. Both Ann and Bob now have the "read right" to view the object.
3. Bob loads another object "DrawerUnit" which contains a drawer unit with 3 drawers. Similar to steps 1 to 2, the drawer unit is displayed on both canvases.
4. Ann tries to modify the table. She changes the shape of the table legs to a rounded shape. This modification is allowed as Bob haven't locked this part. A "write right" which locks the table legs is granted to Ann. All modifications will be forward to Bob at real-time. When Ann's modification is finished, her "write right" can be either withdrawn or kept.
5. Similarly, Bob tries to modify the drawer unit and this writing right is granted.
6. While Bob is modifying the drawer unit, Ann tries to modify the frame of the drawer unit. However, her request is rejected as Bob is still locking the whole object.
7. After Bob's modification, Ann joins the table and the drawer unit. The two objects are now both wholly locked by Ann. Bob cannot modify either object during this joining process. He can only view the changes made by Ann.
8. After joining, the two objects now become a single unit. Bob saves this unit in a file called "WorkingDesk". This save action is sent to the server and Ann is notified.

9. Bob requests to close this collaboration session. Ann agrees and the session is closed. After closing, the viewing canvas will not be affected by other clients anymore.

The above collaborative session is also represented by the following sequence diagram in Fig 4.

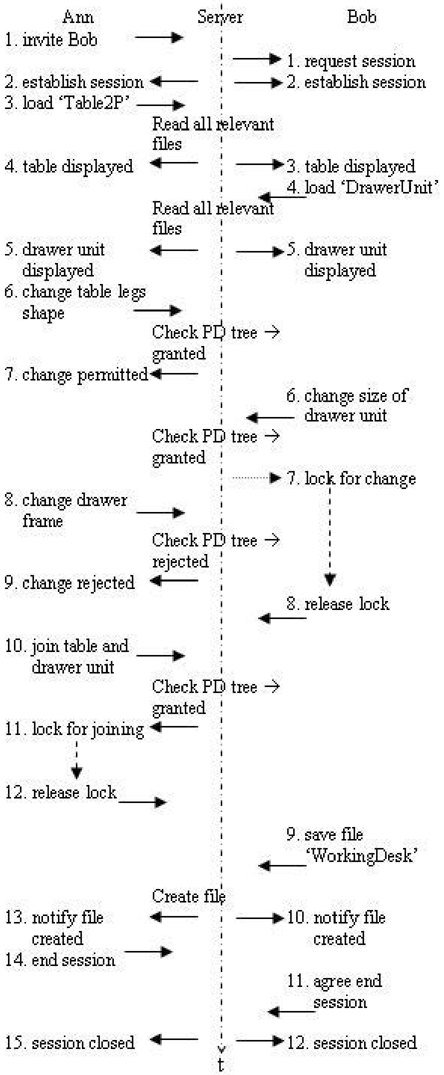

Fig 4. Sequence diagram for Case 1.

The modifications are illustrated in Fig 5a-6c.

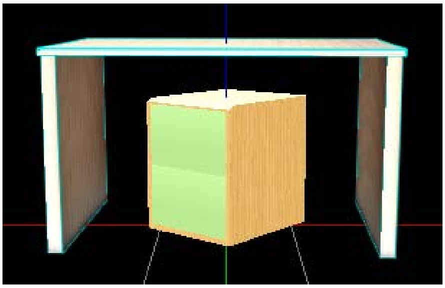

Fig 5a. Table2P and Drawer files before modification.

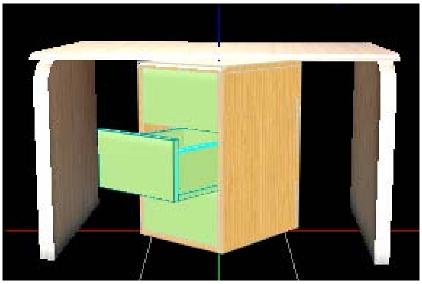

Fig 5b. Table2P and Drawer files after modification;

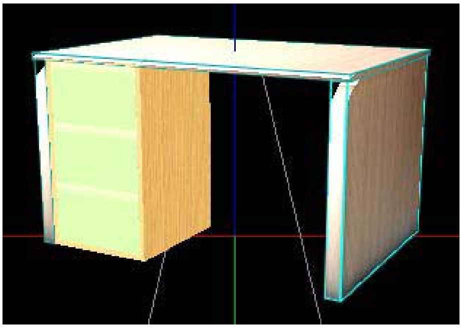

Fig 5c A single WorkingDesk object after joining

4. Conclusion and Future Work

This paper discusses the design and development for a real-time collaborative interactive 3D assembler system over the internet, Co-assembler. We have implemented a prototype of a virtual furniture store. The real-time collaborative design framework is organized by a central server and collaborative Co-assembler clients. We use a client/server approach to the collaborative architecture, as shown in Fig 1. All clients communicate through a common server. All client information are maintained by the server, which also manages the forwarding and broadcasting of design information. The design information is transmitted in the form of basic data types such as integer and string, instead of the generated data (branch or transform groups) which minimize the network traffic. Currently we are working on the version management for the saved files.

Acknowledgement

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Towards PLM based Digital Mock-Up Exchange in Collaborative Product Development

Emmanuel GUYOT[a,b], Sébastien CHARLES[a], Benoît EYNARD[a,1], Thomas GALLET[b]
[a] *Troyes University of Technology, Troyes, France*
[b] *Snecma, Moissy Cramayel, France*

Abstract

Considering a co-developed product, the aim of a digital mock-up is to integrate all geometric data of the same technical framework. It merges internal and partners data of the extended enterprise. This leads partners to exchange and share intensively their products data. This paper aims at describing the IT mechanisms implementation supporting Snecma's data exchanges with partners.

Those mechanisms are based on a PLM interface and an XML processing. The purpose of Snecma is to encapsulate several generic functionalities that can be re-used for all aircraft engine project. It finally appears that such a software architecture provides flexibility, but reusing an application can be limited by some specific needs.

Keywords: Digital Mock-Up, Product Data Exchange, XML, Extended Enterprise

1. Introduction

Considering the world wide market, the development of aircraft and its sub-systems like engines requires strong partnerships in the aeronautics extended enterprise. Some collaborative product development's approaches have to be implemented and an intensive use of IT supports is needed for managing business processes and sharing product data. These IT supports are now based on Product Lifecycle Management solutions (PLM) including a technical framework reference for Digital Mock-Up (DMU).

First of all, this paper introduces the specifications and developments carried out by Snecma (Manufacturer of aircraft turboprop and space engine) for managing product data and implementing the mechanisms for DMU exchange with partners.

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[1] Corresponding author: Prof. Benoît EYNARD
Troyes University of Technology
Charles Delaunay Institute - LASMIS - FRE CNRS 2848
12 rue Marie Curie - BP 2060 - F.10010 Troyes Cedex - France
Tel: +33 3 25 71 58 28 - Fax: +33 3 25 71 56 75
E-mail: benoit.eynard@utt.fr

Section 2 will present the project objectives and the IT support available for the DMU exchange with partners. In section 3, a survey of the main PLM exchange standards is detailed considering PDM Schema, PDM Enablers, PLM Services and PLM XML. Section 4 describes the methods for specifying and developing the exchange functionalities and mechanisms. At last, the preliminary results of a collaborative engine development are assessed in section 5.

2. Snecma PLM project

2.1. Aims of the project

In order to re-engineer its product development processes, Snecma recently choosed to implement a new PLM solution enabling to integrate CAD/CAE/CAM processes and to provide an efficient support for concurrent engineering and the extended enterprise [1],[2]. The aim is to achieve the implementation of a collaborative product development process based on PLM by merging concurrent engineering and extended approaches [3],[4]. Snecma wishes to improve and secure its data exchanges and transfers between the partners of an engine co-development [5].

This means that the PLM solution manages and stores product data, and then distributes them among the whole design team [6][7]. Considering the data geometric definition, it allows an intensive use of 3D data including form features modeling and interfaces specifications to describe a skeleton reference as basis for engine design.

2.1.1. PLM partnership with Dassault Systèmes

In order to reduce the engine development cycles, Snecma is implementing a PLM solution based on the CAx integration supervised by a PDM system [6][8],[9].

This PLM implementation requires a large range of specifications and numerous developments in order to fulfill the particular business and market of aeronautics field [5]. In such a context, Snecma chooses to establish a close partnership with Dassault Systèmes in order to implement the right solution corresponding to its requirements. This solution is mainly based on ENOVIA/VPM for PDM (called VPM bellow) and CATIA V5 for CAD/CAM [10].

2.1.2. PDM workspaces

In order to store and share the product data, Snecma uses three VPM specific workspaces: the working space, the reference space, and the engine space.

The first workspace corresponds to the working space. It is used to store the designers' work in progress.

The second workspace is called reference space. When data is released, designers transfer their parts and assemblies from the working space to the reference space. Then, other designers can use those parts and assemblies as geometric references for modeling its own 3D data. This workspace includes a maturity data manager in order to notify designers which parts can be used as reference.

The last workspace is the engine space. It archives the product Digital Mock-Up (DMU) . This workspace contains and integrates data from the reference space and data from partners. As in reference space, designers can use data from engine space for their design. Snecma has still got a DMU that only handles CATIA V4 CAD files whereas

the company has already migrated his CAD system to CATIA V5. Thus, the purpose of the engine space is to handle CATIA V5 documents and to benefit of the DMU manager's new features and functionalities.

2.2. DMU management

The cost and risks of an engine development bring aircraft engine manufacturers to share their skills and knowledge in close partnerships [11].

In order to help those partnerships, the main goal of the DMU is to integrate the whole engine geometric data and product configuration information based on original CAD files [12]. It conducts to the merging of Snecma and partner's product data in the same reference framework.

This system allows to use the various CAD systems' DMU tools. Designers can analyze the geometric definitions, detect clashes, assess space allocation, and simulate the turboprop disassembling . Based on DMU, they also can evaluate ergonomic and technical constraints during the assembly and maintenance operations, etc.

Basic tools for DMU management are strongly used:

- Clash analysis: this tool lists all the collisions, contacts or clearances in an assembly.
- Fitting simulation: designers can simulate the disassembling of a part and detect collision problems or optimize the number of components to disassemble for maintenance.

All those tools aim to reduce numerous problems in the assembly, working and maintenance phases.

2.3. Exchange with partners

In collaborative product development, each partner has its own DMU system. In order to share the same product modeling, the distributed project teams have to exchange their data and synchronize their digital mock-up.

To coordinate the exchanges, one of the partners has a leadership role as integrator. This role consists in integrating the 3D data of all partners in the DMU reference framework. Then, the integrator distributes all the updated data to the other partners and guarantees the product structure.

Original requirements are:

- a common format for geometry;
- a common meta-data modeling file.

Snecma is the integrator of the engine project on which exchange mechanisms will be implemented. This DMU integration is strongly based on VPM technologies because of strategic choices .

2.4. VPM architecture

The VPM architecture is divided in three parts :

- a file base
- a data base with meta-data (or structuring data)
- an interface with users

The Figure 1 illustrates this specific structure. Meta-data represents the product structure by a tree structure (1). It also contains some information such as revisions, versions, which partners have access to the data, etc. To integrate the product geometry; some meta-data is linked to CAD files stored in a file base (2). The interface (3) allows users to manage product structures and links between meta-data and files.

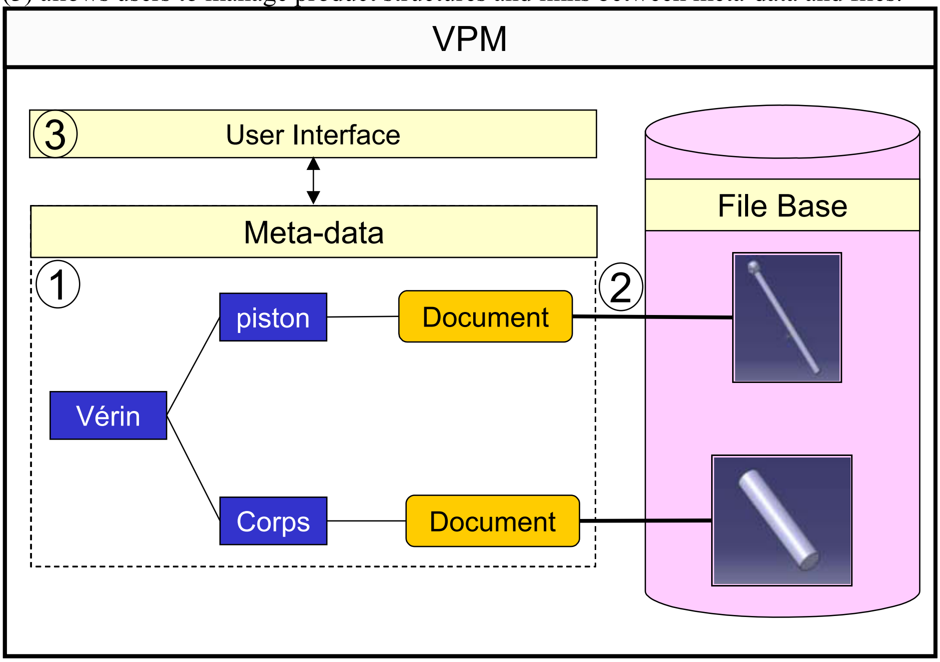

Figure 1: VPM architecture

3. Standards for PLM data exchange

Regarding the constraints between distributed project teams, some standards are required in order to enable the data exchange. Since 15 years, numerous standards have been developed for PLM data exchange [13].

In this section, a brief survey on those standards is done with the PDM Schema, PDM Enablers, PLM Services and PLMXML.

3.1. PDM Schema

STEP (Standard for Exchange of Product model data) is an international standard developed by ISO (International Standard Organization). Its reference is ISO 10303 [14]. This standard proposes various means for storage, exchange and archive of product data in a long-term approach.

Based on STEP parts, the PDM Schema has been specified for exchanges of the data usually handled by PDM systems [15],[16]. This standard is the consistent intersection of definitions and data structures of several STEP application protocols whose fields cover the design and development of models and electromechanical assemblies (AP203, 212, 214 and 232). The PDM Schema results from the co-

operation between ProSTEP (http://www.prostep.org/) and PDES Inc (http://pdesinc.aticorp.org/).

The PDM Schema was developed in order to improve interoperability between STEP application protocols in the field of data management inherent in product development process. The PDM Schema allows the implementation of data exchange functionalities suitable for PDM systems in full compliance with STEP. It enables the interoperability with other applications integrating this standard. PDM Schema also guarantees interoperability with other standards relating to PDM data exchanges such as the PDM Enablers developed by the OMG (see bellow).

3.2. PDM Enablers

The PDM Enablers [17] are APIs (Application Programming Interface), defined in IDL language (Interface Language Definition). They give access to PDM functionalities for any other applications which need them via a CORBA (Common Object Request Broker Architecture) environment. Thus, PDM Enablers APIs can allow CAD, CAM, CAE and other PDM systems to directly handle objects and functions offered by one or more PDM.

PDM Enablers offer direct interfaces to access to the management of documents, product structures, modifications, configurations and specification of manufacturing processes. They include a support for effectivities and project controls. PDM Enablers also offer means to import and export STEP data.

The PDM Enablers give access to the services available in PDM systems. The PDM Enablers define interface models which can be mapped with those of commercial systems. Thus, the objective of the PDM Enablers is not to define a frozen data or PDM application model. They aim to back the most current activities of engineering but not the activities specific to the management of PDM, such as for example the administration of the software and the users.

The strength of PDM Enablers models is the taking into account of the hierarchical and inheritance mechanisms as well as relations between objects.

The PDM Schema and the PDM Enablers are not competing. They should be considered as complementary. Indeed, PDM Enablers can take into account the processes of work and the other dynamic aspects of PDM, as well as the specific data of the companies which extend and/or modify the field of application of the PDM Schema. The assets of the PDM Schema such as its great conformity with STEP and the variety of the data taken into account make of it a format completely adapted to the management of the static aspect of the data exchanges between PDM systems. Thus, the PDM Enablers can be used to manage the dynamic aspect of the exchanges and the PDM Schema for the static aspect.

3.3. PLM Services

The PLM Services is a data model based on the PDM Schema and STEP Application Protocol 214 (http://mantis.omg.org/). The PLM Services implement all the entities defined by the PDM Schema and complete the model with additional entities dedicated to the AP214 schema's configuration management. The definition of PLM Services is based on the PDTnet project's issues carried out by ProsSTEP iViP (http://www.prostep.org/file/15730.Fly_allg). The objective of this project was to

merge AP214 and XML formats in order to simplify the data exchanges between the original equipment manufacturer and its suppliers.

The data model of PLM Services is based on PDM Schema and AP214 entities and takes in consideration the identification of products and CAD models, structures and assemblies of CAD models, management of documents and files, geometric definitions of form features. It also includes the relations of transformation, classification, properties, identification of alias, authorizations, management of configurations, management of tasks and changes, processes definition, and multi-linguistic support.

3.4. PLM XML

PLM XML is a format developed by UGS to facilitate interoperability between PLM solutions using the strength and quality of XML [18]. XML means eXtensible Markup Language, XML is a language structured with tags whose name and organization are not fixed [19]. Due to its tags, the XML structure is derived from SGML and HTML languages and allows users to build their own data structure.

PLM XML offers an efficient and flexible solution to product data exchange via Internet (http://www.plmxml.org). PLM XML is defined as a set of XML schema compliance with the W3C specifications.

The data, taken into account by PLM XML, are product data structure (organization, hierarchization and assemblies), bills of material and products configurations, specific PLM metadata associated with products and models, geometric data (points, curves, reference marks, etc.), relations between users and data (concept of property, user, role and project group), and visualization properties (controls of direction of sight and displaying characteristics).

According to XML features, PLM XML offers numerous possibilities for extension of its data schema definition. Indeed, PLM XML allows creating derived elements from those defined in the schema. Thus compliance with an original schema is guaranteed. PLM XML is strongly customizable and thus efficiently addresses the needs of any kind of PLM solutions.

4. Methods

In order to be able to share and exchange DMU data between distributed project teams and regarding the aeronautics context, the development of a PLM solution based on VPM has been chosen. VPM offers some import/export and interoperability functionalities using some of the above-mentioned standards.

Then, XML format has been implemented for meta-data exchange because it is object oriented language and fully adapted to Internet. It also allows any user to specify its own data structure. Concerning the CAD data, a legacy format is used because current standard like STEP only handled frozen 3D models. This constraint was not acceptable regarding the collaboration requirements of the distributed project teams.

4.1. Data exchange format

The data exchange formats are defined in one common document shared between partners. The formats for the current engine project are: XML for meta-data, and the CATIA V5 release 14 legacy format for 3D CAD data.

The structure of XML file is based on two main elements [20]:

- PARTS_LIST: it corresponds to the list of entities contained in the product structure.
- PRODUCT_STRUCTURE: it describes the links between the part list's entities.

In order to maintain the link between meta-data and CAD files, entities of PARTS_LIST use a pointer on the associated CAD file. This pointer is the name of the CAD file.

4.2. Import/export PDM

Exchange with partners involves two tasks based on classical import/export operations: sending PDM data to partners and integrating partner's data in the PDM.

To send the data, it is necessary to extract them from the PDM. Thus two applications are used:

- meta-data export: this application extracts meta-data from the PDM and writes them in a XML file.
- CAD files extractor : this task consists in extracting CAD file from the PDM.

To integrate partner's data in the PDM, an application called "import data" is used to update PDM data base with a XML file and associated CAD files.

4.3. XML filters

The XML file exported from the PDM contains the whole product description. But Snecma does not need to send all the data of this XML file.

To filter the XML file, Snecma implements three kinds of filter:

- root seeker: this filter seeks for particular XML entities in the product structure and sends back an XML file describing this structure only based on the entities definition.
- Attribute value: this filter deletes all XML entities without the attribute value described in the filter.
- Attribute value existing: this filter tests if at least one XML entity has an attribute value described in the filter.

4.4. XML translator

The export and import applications do not use the same XML format than exchange format. Thus it is necessary to translate XML file with an application. The procedure used is called mapping: it aims to map and maintain consistency between the two XML attribute lists (see example Figure 2).

Import/export XML attribute	Exchange XML attribute
S_REF_ARTICLE	REFERENCE
S_SOCIETE	SOCIETE

Figure 2 : Mapping between XML attribute Lists

4.5. Exchange mechanisms architecture

The above presented applications (import/export, XML filter, XML translator) are integrated in exchange mechanisms (Figure 3).

- Export phase : CAD geometries are extracted from DMU (step 1.1) and converted in exchange format (step 1.2). Then, the whole DMU's product structure is extracted as xml (step 2.1). The xml is filtered in order to keep the useful data (step 2.2). Then, the xml file is translated to the exchange format (step 2.3). The xml and associated geometries are packed (2.4) and sent to partners (step 2.5).
- Import phase : Snecma receives package from its partners (step 3.1) and unpacks it (step 3.2). The xml contained in the package is translated in DMU import format (step 3.3) and partners' geometries are analyzed before integration (step 4.1). At last, the xml translated is used to update DMU's product structure (step 3.5).

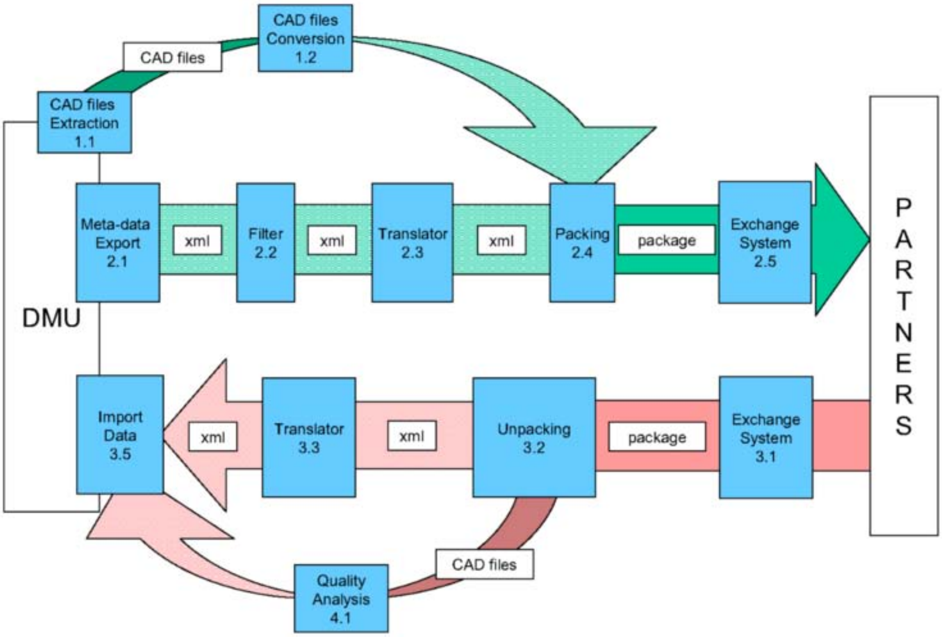

Figure 3 : Exchange mechanism

The aim of exchange mechanisms is the flexibility of information processing: first, all applications are configurable. So for each of them a large scope of use is possible; second, applications have to be standardized so they can be directly re-used for other engine projects.

5. Preliminary results

5.1. Migration

The first use of exchange mechanisms was the migration of the former DMU to the new one.

For this migration procedure, it has been considered that the former DMU was a partner for the new one. All data (meta-data and CAD files) has been exported from the former DMU in the exchange format. Last step of the migration has been the data translation and import into the new DMU.

Because of the applications flexibility the migration took three days.

5.2. Implementation of an engine project as case-study

Implementation of exchange mechanisms on a new project is under progress. At this time, the former exchange mechanisms are still being used to synchronize the former DMU with the new one. This synchronization is ensured based on the new exchange mechanisms.

On the one hand, this intermediate step allows validating the new exchange procedure as these mechanisms are tested and used in real conditions. On the other hand, it gives the possibility of quantifying the required time for the data extraction from the new DMU: in comparison with the former DMU there exists a 5 ratio (150 minutes with former DMU, 30 minutes with the new one).

The next step in the implementation process is the automation of all the procedure and after, a new application will be carried out to deploy the whole exchange mechanisms.

5.3. Generalization for the others engine projects

The next project step will be the implementation of exchange mechanisms in a new engine project. Snecma's objectives for this new project are to use the same exchange functionalities than the first engine project.

But at this time the limits of the system are reached: the second engine project requires new developments for the import data functionality because of specific needs from partners on this engine project.

As far as the deployment of all mechanisms for DMU exchanges is concerned, this means that some improvements are required concerning the global approach of partnership exchange and robustness requirements regarding the IT support [21].

6. Conclusion and future works

In this paper, the preliminary developments of a PLM based DMU management are detailed. These works have been carrying out for aeronautics extended enterprise and especially for the collaborative development of turboprop.

Currently the specified IT support for DMU exchange between project partners is under assessment and improvement. Regarding one specific engine project, the obtained benefits on data extraction time from the DMU manager are really relevant

about a 5 ratio. But this engine project has got the advantage of huge technical support from the IT team members involved in the project.

In order to be able to improve the developed DMU exchange mechanisms, several engine projects have to be carried out. Then, they will provide some feedback on the efficiency and robustness of the implemented mechanisms and they will allow validating the IT choices such as XML or legacy CAD format.

Future works will have to take in account the business processes and collaborative organization to be implemented in order to merge IT and human aspects as success factor of such a collaborative product development and extended enterprise strategies for Snecma and its aeronautics partners.

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Conflict Management in Design Process: Focus on Changes Impact

K. GREBICI [a,1], M-Z. OUERTANI [b], E. BLANCO [a],
L. GZARA-YESILBAS [b], D. RIEU [c]
[a] GILCO-INPGrenoble, 46 Avenue Félix Viallet, 38031, Grenoble Cedex, France
[b] CRAN – UHP Nancy I, BP 239, Vandoeuvre-lès-Nancy, 54506, France
[c] LSR-SIGMA- IMAG, 2 Place Doyen Gosse-38031-Grenoble Cedex, France

Abstract: Design has increasingly become a collaborative endeavour carried out by multiple actors with diverse kinds of expertise. A critical element of collaborative design is to manage conflict, emerging due to the multi-actors interaction, and particularly the impacts once the conflict is resolved. Indeed, the conflict resolution comes up with a solution which often implies modifications on the product and the process organisation. This paper deals with this problematic of changes impact on conflict management process. It quantifies key issues with regards to concurrent engineering that enables us to better manage the design process. Strategies to overlap coupled activities are proposed based on the dependencies between the handled data during the design process.

Keywords: Conflict management, changes impact, data dependencies, overlapping strategies

Introduction

Due to multi-actors interaction in collaborative engineering design, conflicts can emerge from disagreements between designers about proposed designs. Therefore, a critical element of collaborative design would be conflict resolution. In a collaborative design context, conflicts occur when at least two incompatible design commitments are made, or when a design party has a negative critique of another design party's actions [1]. The conflict management process could be perceived as the succession of five phases: Conflict detection, Conflict resolution team identification and formation, Negotiation management, Solution generation and Solution impact assessment.

Current conflict management approaches in collaborative design focus on *Conflict detection* [1] [2] [3], *Negotiation management* and *Solution generation* phases [4] [5] [6] [7].

In a previous work [8], we proposed a methodology, called DEPNET[2], to tackle the *Conflict resolution team identification and formation* phase. This methodology addresses the problematic of identifying the actors to be involved in the negotiation process to resolve the conflict. Based on a process traceability system, the DEPNET methodology consists of identifying and qualifying the dependencies between the data

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1 Corresponding Author: Khadidja Grebici, E-mail: grebici@gilco.inpg.fr
2 Product Data dEPendencies NETwork identification and qualification

handled during the design process execution. This leads to the construction of a data dependencies network which allows identifying the actors to be involved in the conflict resolution process. Indeed, each data is carried out by an activity. This activity has a responsible to execute it. Consequently, once a data is identified, the actor responsible for its realisation is identified.

Concerning the *Solution impact assessment* phase once the conflict is resolved, it has not been tackled on the reviewed works. Indeed, the selected solution often implies the modification of one or more input data of the activity where the conflict has emerged, and thus, generating a cascade of modifications on the already produced data. Consequently, these data have to be redefined. This implies re-executing the various design activities responsible on the elaboration of these product data and also adjusting the process still in the pipeline. Accordingly, strategies are to be proposed to coordinate re-execution of the concerned activities. Hence, this paper purposes' is to come up with strategies to coordinate the activities re-execution. In order to do so, we based ourselves on the data dependencies network, already built thanks to the DEPNET methodology, to identify the impacted data to be redefined, as well as the correspondent activities to be re-executed.

The remaining part of the paper is organised as follow. First, section 1 presents the data dependencies network constructs. Then, section 2 describes the mechanisms to identify the impacted data and their correspondent activities once a solution is selected. Section 3 presents a set of activities re-execution strategies. Finally, section 4 discusses and concludes the paper.

1. Data Dependencies Network Constructs

The data dependencies network is an oriented graph composed of nodes and arcs (cf. Example Figure 1):

- Nodes correspond to the product data handled during the design process and leading to the elaboration of the data source of conflict, i.e. the set of data on which this source of conflict depends. These product data can be of several types such as: structural, functional, behavioural, geometrical, etc. They correspond to the various descriptions of the product, elaborated by designers during the development process, in terms of geometrical entities, functions, bills of materials, CAD models, calculation notes, etc.
- Arcs correspond to the dependency relationships between the various nodes identified in the network (data). In a context of collaborative design, dependency between two data could be on *forward* or *feedback* direction. Forward dependent data are those that require input from other activities, but not themselves. Feedback dependent data are those that need inputs from other activities including themselves. The feedback links are to be considered since they are a source of rework and thus are resources consuming and time consuming. Thus, two data are said to be dependent in the case of forward dependency or interdependent in the case of feedback dependency.

The dependency relationships in this network are quantified with a dependency degree which is an aggregation of the three attributes: completeness (adapted from [9], variability (adapted from [10]) and sensitivity (adapted from [10]) (cf. Eq. (1)).

$$\textit{Dependency Degree} = \textit{Completeness} * \left(1 + \left(\textit{Variability} * \textit{Sensitivity}\right)\right) \qquad \textbf{Equation 1}$$

These attributes are valued by actors when they capture their activities in the design process traceability system. In practice, these attributes are not always easy to define quantitatively. Therefore, using structured expert interviews, qualitative inputs are developed to provide insights on how to evaluate them. The *Completeness* **(C)** expresses the suitability of an input data to the creation of an output data (0 Weak, 1 Not Vital, 2 Vital and 3 Extremely Vital). The *Variability* **(V)** describes the likelihood that an output data provided by an activity would change after being initially released (0 Not Variable, 1 Low Variability, 2 Moderate Variability and 3 High Variability). The *Sensitivity* **(S)** describes how sensitive the completion of an output data is to changes or modifications of an input data. It expresses the degree to which work is changed as the result of absorbing transferred data (0 Not Sensitive, 1 Low Sensitivity, 2 Moderate Sensitivity and 3 High Sensitivity).

As completeness, variability and sensitivity are valued with numerical values (0, 1, 2 and 3), the resultant range value of the dependency degree is an integer between 0 and 30, whereas {0, 1, 2, 3, 4} denotes a weak dependency and a low risk of rework, {5, 6, 7, 8, 9, 10, 12, 14} describes a moderate dependency and a moderate risk of rework and {15, 20, 21, 30} denotes a high dependency and a high risk of rework.

Based on the data dependency network and thanks to a set of SQL queries on the database storing the process execution instances, it is possible to identify for each data of the network, the activity responsible on its elaboration as well as the actor performing this activity. In the next section, we detail how to evaluate the impact of a selected solution once the conflict is resolved.

2. Solution Impact Assessment

The technical solution selected through the negotiation and resolution phase corresponds to the change of one or more product data involved in the design process leading to the elaboration of the data source of conflict. The data to change is then a part of the data dependency network presented in Section 1. Hence, assessing the selected solution impact returns with propagating the impact of those data changes through the data dependency network and thus on the organisation of the responsible activities. For example, in the case of a conflict occurring on the piece of data D6 (cf. Figure 1), supposes that the solution retained after resolving that conflict consists of changing the piece of data D9 value. Consequently, according to the data dependency network, all data linked to D9 with a forward dependency relationship (arrow starting from D9) must be changed, i.e. data D1, D2, D3 and D4. Then, all data depending on D1, D2, D3 and D4 must be changed, i.e. D5 (depending on D4), D6 and D10 (depending on D2), etc. Therefore, activities responsible of the elaboration of D1, D2, D3, D4, D5, D6, D10, etc. have to be re-executed. In this example, the total number of solution (D9) depending nodes is low (10 nodes) and re-execution of the design process is simple. In case of complex products, whereas the corresponding data dependency network is huge, identifying the solution depending nodes and then the design activities to be re-executed may be ad-hoc and costly task. Not all the activities responsible of the identified depending data will be re-executed; such an operation is costly and time consuming. Thus, a concept of *critical Data Dependency Network* is introduced in order to reduce the number of solution depending nodes to consider for design process re-execution. In other words, this consists of eliminating data having low dependency

degree and their entire successors among the impacted data[3]. Hence, based on the critical data dependency network, the identification of the activities to be re-executed is performed. Indeed, a set of SQL queries applied to the process execution database allow identifying the activities responsible on the elaboration of the critical data network nodes, the actors performing these activities as well as the input data and output data of each activity. Then, the actor responsible of the change management has at his disposal the set of activities to re-execute with the associated actors and Inputs/Outputs. Based on the input and output data, the order of executing activities can be determined. Indeed, when the output of an activity A corresponds to the input of another activity B, that means that activity A precedes activity B. In this paper, the focus is put on the resulting activities re-execution organisation. The aim of organising activities re-execution is to minimise the re-execution time by decreasing the probability and the magnitude of iterations in the newly executed process. This can be done by enhancing activities' overlapping and concurrent execution. In Section 3, a set of coordination strategies are proposed based on dependency degree values.

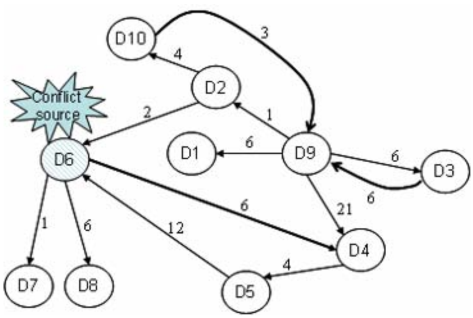


Figure 1. Example of data dependencies network

3. Design Process Re-execution Strategies

Depending on the dependency condition of the data to be changed (variability, sensitivity and completeness), i.e. depending on the probability of iteration on both feed forward and feedback dependencies between associated activities (those producing and those using the data to be changed), different strategies for re-executing these activities are examined.

Inspired from the coordination strategies developed by [10] and [11], a set of coordination strategies, i.e. ways of ordering activities and diffusing data, are proposed. First, we discuss the case of *dependency*, i.e. data linked with only feed forward dependency. Then, the case of *interdependency* is treated, i.e. data linked with both feed forward and feedback dependencies.

3 The methodology proposed to identify the critical data dependency network is not presented in this paper; it will be developed in a future publication.

3.1 Dependency Case: Only Feed Forward Dependency

This case concerns two activities A and B, respectively producing data D1 and D2 where D1 and D2 are linked by feed forward dependency (cf. Figure 2).

In this section, different values of completeness (*Weak, Not Vital, Vital and Extremely Vital.*) are considered and for each case, depending on variability and sensitivity values, strategies of coordination are suggested.

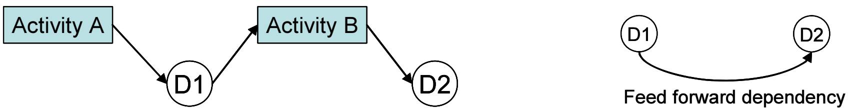


Figure 2. Dependency case

Case 1: if the upstream data (D1) is *weak* (Completeness of D2 = 0), for every value of the variability V of the upstream data (D1), the execution of the downstream activity (B) does not require the considered data (D1). Thus, the adopted strategy would be the execution of the involved activities in early overlapping way. This means both activities A and B execution can begin at the same time without any risk of iteration.

Case 2: if upstream data (D1) is at least *not vital* (Completeness of D1 ≠ 0)

***Case 2.1: if the upstream data (D1) is not variable (Variability of D1 = 0)*,** for every value of sensitivity S of downstream data (D2), the required upstream data (D1) is not variable (V=0). This means when the upstream data D1 is ready to be diffused, the downstream activity B starts earlier with finalised information D1. Thus, the corresponding re-execution strategy is a "pre-emptive overlapping" (see case 2.3 below).

***Case 2.2: if the upstream data (D2) is not sensitive (sensitivity of D2 = 0)*,** for every value of the variability V of the upstream data (D1), there is no impact in the downstream. Thus, the strategy of re-execution is based only on upstream completeness values and it represents a "thrown over the wall overlapping", where activity A diffuses preliminary data (D1) corresponding to the required (by activity B) completeness value (C=1, C=2 or C=3).

***Case 2.3: if the upstream data (D1) is at least low variable, the downstream data (D2) is at least low sensitive (Variability of D1 ≠ 0 and Sensitivity D2 ≠ 0) and the upstream data D2 is Not Vital (C=1)*,** the uncertainty conditions depend only on the upstream data (D1) variability and the downstream data (D2) sensitivity. Table 1 summarizes the different coordination strategies depending on D1 variability and D2 sensitivity values (a preliminary data exchange is represented by a discontinued arrow, and a finalized data is represented by a full arrow). The various proposed strategies are defined in the following.

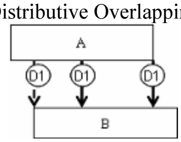
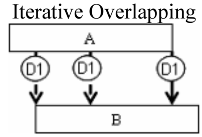
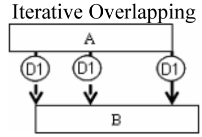
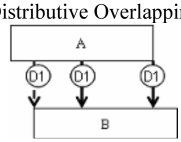
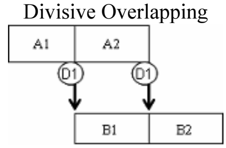
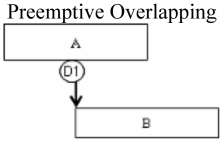
- *Distributive overlapping*: makes possible to both start downstream activity (B) with preliminary information and to pre-empt later changes in the exchanged upstream data (D1). The impact of overlapping is distributed between upstream and downstream activities, thus this strategy is called distributive overlapping.

- *Iterative overlapping*: the activities are overlapped by beginning the downstream activity (B) with preliminary information, and incorporating design changes in subsequent downstream iterations. The overlapping is said to be iterative.

- *Preemptive overlapping*: When variability of upstream data (D1) is low (V=1), information can be frozen earlier than its normal freeze time. This will allow high sensitive (S=3) downstream data (D2) to start earlier with finalised information. In such a case, the exchanged information is to be pre-empted by taking its final value at an earlier point in time. This is called pre-emptive overlapping and would help to reduce design time by starting the downstream activity earlier but with frozen upstream activity information.

- *Divisive overlapping*: the information (D1) is disaggregated into components to see if any of the components have low variability or if transferring any of the components in their preliminary form to the downstream activity is practical.

Table 1. Dependent activities coordination strategies

	Low_V (1)	**Medium_V (2)**	**High_V (3)**
Low_S (1)	Distributive Overlapping 	Iterative Overlapping 	Iterative Overlapping 
Medium_S (2)	Distributive Overlapping 	Activity and dependency link redefinition	Divisive Overlapping 
High_S (3)	Preemptive Overlapping 	Multifunctional Team (Concurrent Execution)	Multifunctional Team (Concurrent Execution)

- *Activity and dependency link redefinition*: this strategy calls for disaggregating predecessor design information (D1) into two or more information fragments that can be released (as incomplete or partial design information) earlier than the planned one-shot release. Consequently, the follower (i.e. downstream) activity (B) is broken into n sub-activities, where each sub-activity utilizes one upstream information (D1) fragment. There is no general rule for the optimal number of upstream partial information pieces required or the number of downstream activity breakdowns. This depends on the specific design situation being analysed and requires a thorough understanding of the design process details.

- *Multifunctional team (concurrent execution)*: The basic goal of such a strategy is to guarantee that downstream concerns are considered upstream. This will result in: decreasing variability of a predecessor due to the fact that upstream activity engineer(s) are working closely with downstream activity engineer(s); and lower sensitivity value of the successor (D2) due to the instantaneous feedback accomplished by the multifunctional team.

Case 2.4: if the upstream data (D1) is at least low variable, the downstream data (D2) is at least low sensitive (Variability of D1 ≠ 0 and Sensitivity D2 ≠ 0) and the upstream data D2 is at least Vital (C ≤ 2). If upstream completeness is vital

(C=2) or extremely vital (C=3) then the interest is to avoid as much as possible upstream rework because this induces long iterations. Thus given low sensitivity (first row of Table 1), and medium or high variability, it is more interesting to realise coordination with less preliminary diffusion as possible; this means to prioritize distributive then iterative overlapping in order to reduce upstream iteration. However, if variability is low (first column in Table 1) and downstream sensitivity is medium or high, pre-emptive is more interesting then distributive overlapping in order to reduce iterations in both upstream and downstream activities.

3.2 Interdependency Case: Feed Forward and Feedback Dependencies

In most product development processes, interdependency between activities is essentially a one-way dependency between an upstream activity and a downstream activity with a feedback dependency from the downstream activity to the upstream activity (Figure 4). When the development process involves interdependent activities, it is divided into two stages: a planned stage and a random iteration stage. The first stage contains only the initial attempts of both activities. The second stage contains all the subsequent design iterations of both activities. There is no confusion on what activity to start first in this case.

The first stage consists of coordination strategy according to forward dependency degree between upstream and downstream (case § 3.1). The second stage represents coordination strategy according to feedback dependency degree between downstream and upstream.

As an illustration, we consider the interdependent activities in Figure 3 (Activity 9 and Activity 3 corresponding to data D9 and data D3 respectively from the Figure 1).

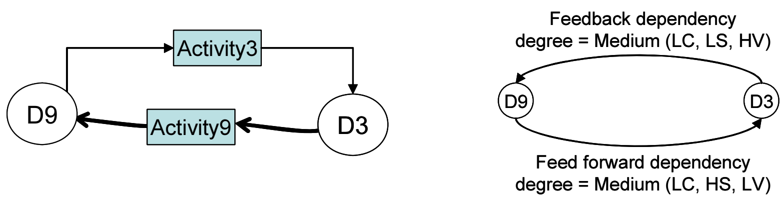


Figure 3. Interdependency case

In this example, forward dependency degrees are Medium (Low Completeness, High Sensitivity and Low Variability) and feedback dependency degree is medium (LC, LS and HV). Thus, the first step (coordination strategy between activity 3 and activity 9) corresponds to pre-emptive overlapping. Once activity 3 is ready to diffuse D3, the second step is launched and iterative overlapping is applied (Figure 4).

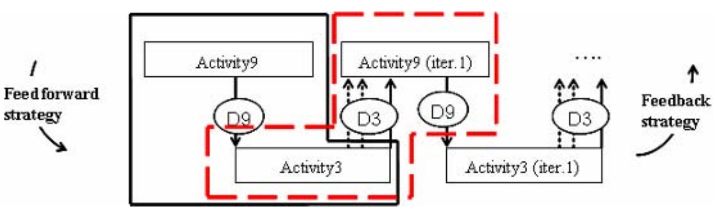


Figure 4. Coordination strategies of interdependent activities

4. Conclusion

In this paper, an approach to address the problematic of solution impact assessment is presented. This approach is based on a data dependencies network in order to identify the impacted data as well as the correspondent activities. Then, a set of strategies to coordinate the activities to be re-executed is proposed based on the three attributes Completeness, Variability and Sensitivity. These strategies are inspired by some research works addressing the overlapping problem by developing approaches to study Concurrent Engineering (CE) process [10] [11] [12] [13]. These approaches help when and how two development activities should be overlapped. The feasibility and acceptability of these coordination strategies have been validated on an industrial case. However, these approaches propose coordination strategies regarding only two attributes; variation and sensitivity and to coordinate only two activities. In this paper, we proposed to extend these approaches to the entire design process. Furthermore, the present approach relies on the definition of the data dependency network which is not the case with previous approaches.

Currently, the present approach has not been yet validated. A tool to support this methodology is under development to enable experimentation in an industrial context.

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Towards Agent-Based Collaborative Design

Md. Mosharrof Hossain SARKER
Dept. of EEE, Islamic University of Technology, Gazipur-1704, Bangladesh

Abstract. A complex system is concerned with several differential stages and heterogeneous skills of partners. To complete this type of design within a specific timeframe and with a reasonable cost, the task of design is distributed by nature. Getting geographically dispersed partners together to collaborate on a joint project is costly and time consuming. Developing a virtual teamwork based on web technology where the partners can express their opinions without traveling could reduce the complexity to meet them together in a place. With the advent of the internet and the techniques available from Distributed Artificial Intelligence (DAI), electronic collaborative design has become possible. Therefore, descriptions of architectures of query agent and manipulating agent are given, and two agents are considered for distributed collaborative design. One agent is dealing with T-Bar while the other agent is dealing with C-Bar. A typical square bar consisting of T-Bar and C-Bar is built using "*Point to Point*" notion. Knowledge Query and Manipulating Language (KQML) is used as a protocol for knowledge and information exchange.

Keywords. Agent, Concurrent Engineering, KQML

1. Introduction

Design of a complex system is concerned with several differential stages and heterogeneous skills of participants. To complete this type of system within a specific timeframe and with a reasonable cost, the task of engineering design is distributed by nature. Developing a virtual teamwork based on web technology where the participants can express their opinions without traveling could reduce this complexity. With the advent of the internet and the techniques available from Distributed Artificial Intelligence (DAI) electronic collaborative design has become possible.

Concurrent Engineering (CE) is concerned with product development across organization and its effectiveness. As a part of CE, Computer Supported Collaborative Work (CSCW) promises to provide a basis for virtual design environment where the participants can express their opinions without traveling using internet/intranet for communication. With the proliferation of CSCW and idea from Artificial Intelligence (AI)/Distributed AI tools, particularly multi-agent systems is to provide automatic / semi-automatic collaborative design [1][3][4]. This paper presents frameworks and a simple prototype of collaborative design using KQML.

1.1. Agent

Software Agents (SAs) are computer programs that carry out some set of operations on behalf of a user or another program with some degree of independence or autonomy, and in doing so employ some knowledge or representation of the user's goals[2][5]. SA

exhibits number of characteristics: agency, autonomy, mobility, cooperation, and so forth. Certain characteristics are, arguably, the best way to describe what an agent is, and what it is not [2].

- *Autonomy*: The agent's ability to decide on actions without having to ask a user. The more seldom it has to consult a user, the higher the degree of autonomy.
- *Agency*: An agent works on behalf of an 'owner'. The 'owner' can be a human user or another agent.
- *Co-operation*: Agents can collaborate with humans and/or other agents to satisfy specific goals. They can be endowed with an ability to communicate, negotiate and resolve conflicts.
- *Mobility*: Agents can move to other environments. They can carry data and intelligent instructions, which can be executed remotely.
- *Co-ordination*: It is a process in which agents engage to ensure a community of individual agents acts in a coherent manner.
- *Learning*: Agents can exhibit some ability to learn from their environment.

1.1.1. Agent Versus Object

Agent technology deals with both object technology and software engineering, which are the major areas of information technology. Object technology represents object component as object whereas agent technology represents them as agent [3][6]. Agent exhibits autonomy that objects don't. Communication in agent is much more sophisticated then in object.

1.2. Structure of the paper

This paper consists of six sections. Section 1 briefly introduces collaborative design and software agents. Section 2 presents related work. Section 3 presents the design object used in this work. Section 4 presents architecture of agent-based design. Section 5 describes the collaborative design. Section 6 concludes the paper.

2. Related Works

A number of researchers [3][4][5][8][9] have referred to the use of agent-based systems to support engineering design. There are several research projects in the field of agent involved collaborative design.

Nowak *et al*. (2002) presents a conceptual framework for distributed product development management, and gives synchronous knowledge exchange in collaborative design.

Su *et al*. (2002) presents an collaborative environment for design and manufacture supported by internet. AutoCAD is considered for design purpose.

Fujita and Akagi (1999) presents an agent-based distributed design system to design a complicated large engineering system. C language is used as a platform to design a ship.

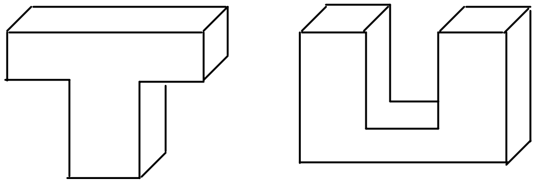
Haohan *et al.* (1997) explores a collaborative design system CCAD-II, identifies distributed system is more complex than centralized system, presents agent communication applying four policies.
The previous works paid no attention to agent–based collaborative design using KQML.

3. Object Used in Design

Engineering design follows the systematic and creative application of scientific and mathematical principles. Object used in this work may consider as [6]: To design an object a representation, which is suitable for computer manipulation.

3.1. The Design Objects Used for this Work

For the purpose of this work the distributed element of engineering design is simulated using a simple task of integrating two simple objects. The first object is the T-Bar, which looks like the English alphabet T. The second object is the C-Bar, which looks like the English alphabet C. The 3-D views of both objects are depicted in Figure1.

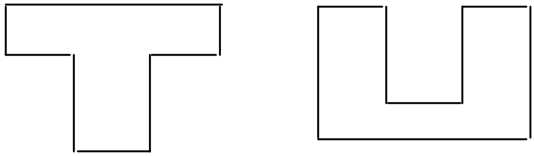


(a) (b)

Figure 1. 3-D views of (a) T-Bar, (b) C-Bar

To simplify matters further, and given time constraints, two-dimensional versions of the T-bar and C-bar objects are considered. This will make the task of connecting the parts simpler without loss of generality. Engineering knows about the expected shape of a design, but techniques from mathematics are available for calculation of engineering design. From *Divergence theorem*, we get volume integration is equal to surface integration. So, the views of 3-D objects are shown in the views of 2-D objects.

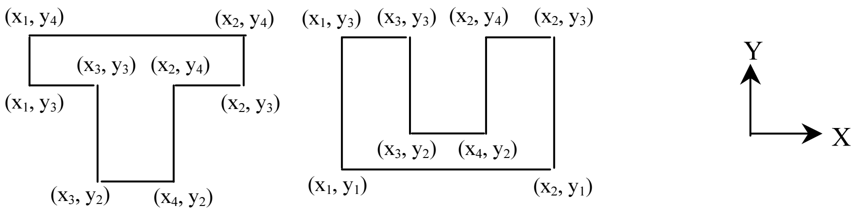
$$\iiint \nabla \cdot \mathbf{A}\, dv = \iint \mathbf{A} \cdot \mathbf{n}\, ds$$



(a) (b)

Figure 2. 2-D views of (a) T-Bar, (b) C-Bar

From the viewpoint of software engineering as well as geometric notion, a straight line can be drawn if the initial point and the final point are known. Both T-Bar and C-Bar consist of eight lines, which mean we should at least concern about eight points for both of the bars as depicted below. Therefore, each line of T-Bar / C-Bar can be drawn.



4. Description of Agent and Computer Environment

Architecture is the science and art of selecting and interconnecting components that meet functions, performances, and goals. Each agent uses its own Knowledge Sources (KSs) for design purpose.

4.1 Agent Communication

An agent operates generally by receiving input via sensors, deciding an action and performing action. On of the ways to communicate an agent with another agent is massage-passing mechanism [3][5][10]. Internal message (active/passive) is sent from an agent to another agent within a system. External message (active/passive) is sent from a system to another system.

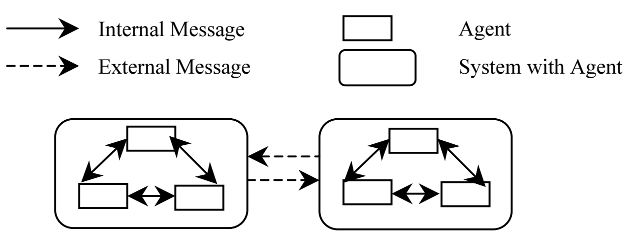


Figure 3. A system with Agents with messages

Different languages, different data format, and different platforms have been using for representing knowledges. Knowledge Query and Manipulating Language(KQML) is a protocol for knowledge and information exchange. KQML is structured in such a way to support software agent communication. The use of facilitator – a piece of agent called facilitating agent, and the use of router – a piece of process are exhibited in KQML [10].

```
(tell / Ask                 ’ KQML performative
    : sender     < >
    : receiver   < >
    :language    < >
```

:ontology : < >
:content < >)

4.2 Architecture of Distributed Agent

4.2.1 Query agent

Query agent made inquiries of all those who are present. It deals with design data between agents.

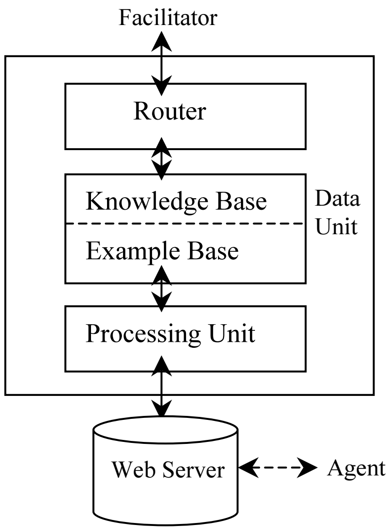


Figure 4. Query Agent Architecture

Data Unit **:** It could define as a unit where data is stored. It consists of two sections: *Example-base*, and *Knowledge-base*.

- *Knowledge-base***:** Knowledge-base has knowledge about dependency and concurrency in design computation. In design, attributes execute design activities and their values are dependent variables. For example, if there are three attribute variables, such as, 'a = b + c'. The value of 'a' depends on the value of 'b' and 'c' respectively [3][5].
- *Example-base***:** A number of examples are given in example base. If any information matches with the given examples, query agent tries to solve the problem with it. For example , from *Euler* idea in geometric and solid modeling, the arithmetic sum of vertices, faces, and edges of a design object (e.g., T-Bar / C - Bar) is constant. Using this idea, (7-11+7 = 3) and (10-11+5 =4) are given, the third one can be formed from the given examples [6].

Processing Unit**:** The processing mechanism is "*Point to Point*". It realizes the data query, makes decision, and executes it.

4.2.2 Manipulating agent

Design Unit**:** Design unit is a heuristics presentation of design ideas. A simple piece of design has a number of positions and positions are detected as points where each point has 3 attributes: Co-ordination (x,y), link, and path.

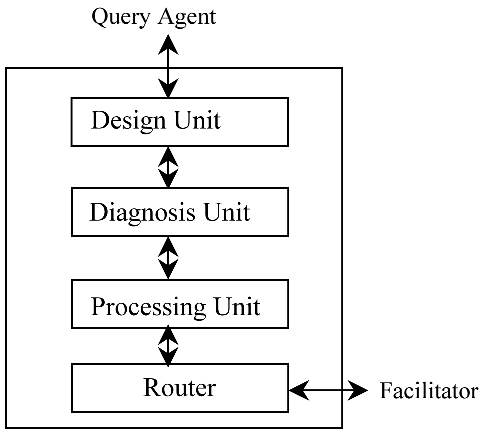


Figure 5. Manipulating Agent Architecture

Diagnosis Unit**:** It is important because how a process is supposed to work is helpful to know for why a process is not working correctly [3]. For example, there are a number of fitnesses of an engineering design, such as, clearance fit, interference fit and so forth. *Clearance fit*, if T-Bar exactly fit with C-Bar without hassle. *Interference fit*, if T-Bar fits with C-Bar after any modification in design.

Processing Unit**:** It deals with preparation of collaborative design application and supporting documentation for consideration.

4.3 Computer Environment

A simple collaborative design protocol is established using JAVA language where the agents are under the same facilitator instead. The program is linked with HTML page(s), and APPLET is declared in HTML page(s) to support collaborative design in Internet environment.

5. Agent-Based Collaborative Design

5.1 Knowledge Sources

It is a place that is the origin or prime cause of knowledge. It needs solving problems. For design purpose the Knowledge Sources (KSs) can be presented as logical

conditions, algorithms, and methodologies. KS contributes to the evolving problem solution in the decision making process.

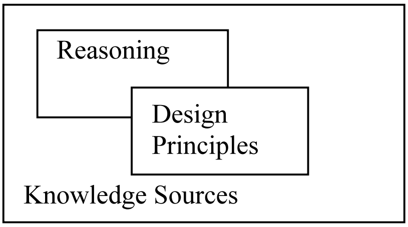


Figure 6. Structure of knowledge source

Reasoning starts with an initial data and continues until the final data are reached when all the involved KSs unanimously agree / disagree about a design decision. It means no modification is further possible. A simple taxonomy is presented on behalf of reasoning because it varies from stage to stage, but overall goal is the same.

Interference (i.e., it is shown in scenario2) is presented here particularly because mismatch generally appears in collaborative design. Re-allocation is an important step to avoid interference; afterward modification abates the whole process to a sound collaborative design.

Design principle determines, for example, a reference surface, parallel / perpendicular to the first surface, parallel / perpendicular between surfaces, and so forth.

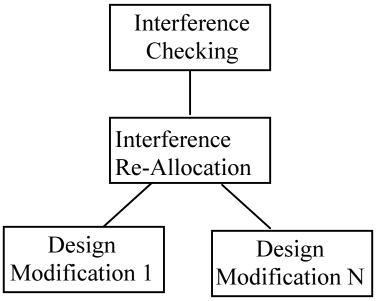


Figure 7. A 3-level reasoning stages

5.2 Data Structure

The data is arranged in array structures to demonstrate a simple prototype. When an agent communicates with another agents, it delivers information about three attributes (e.g., co-ordination, link, path) of a point. Co-ordination is the geometric position of a point, Link draws the relationship of a particular point to others, and Path denotes the affected area in this process. The attributes of a point is linked with one another in array structures. Therefore, a typical square bar is designed.

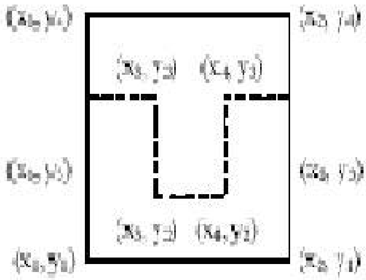


Figure 8. Typical Square Bar

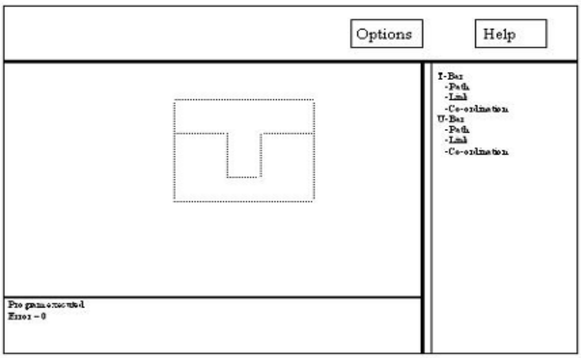
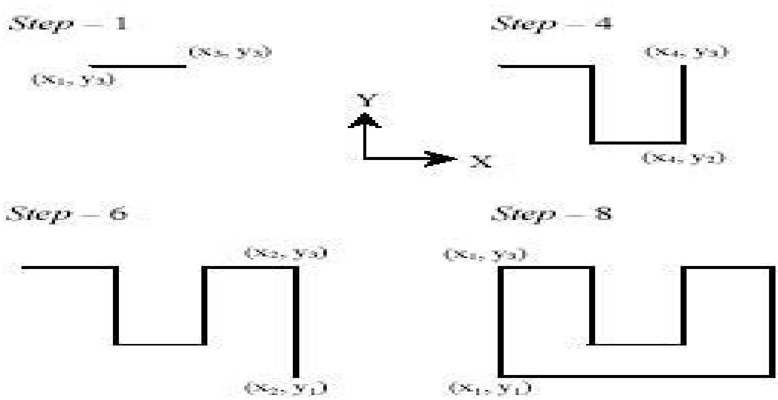


Figure 9. Screen View of collaborative design

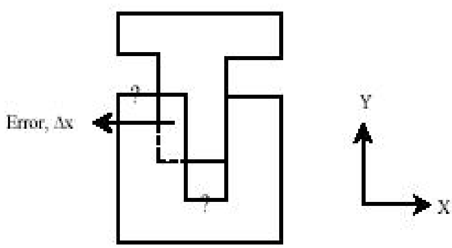
To mediate intelligent agent for collaborative design using ZEUS agent building toolkit is a potential mean. The activities of agents can be exhibited as scenarios where two agents are dealing with a particular design of a product where both of them are suppliers. The versatility of these scenarios may not have enough potential for current applications.



Scenario 1 – *Introducing between agents*: President of a UK wing design and manufacturing company has instructed Agent 1 to look for a C-Bar to design a square bar where T-Bar is available to Agent 1. Being positive feedback. Agent 2 has sent a

positive feedback to Agent 1 to supply C-Bar. Agent 1 has recorded the name of Agent 2 into its list. One agent communicates with another agent for each line (e.g., initial point and final point of line), which means eight steps to concern about either whole T-Bar or whole C-bar. Among the eight steps, only four steps are described above where agent 1 asks agent 2 about C- Bar.

Scenario 2 – *Conversation about design*: Agent 1 has given the description of T-Bar (e.g., *length, width, height* etc.). Agent 2 has replied to Agent 1 that the proposed C-Bar could fulfill all requirements except one. The whole of C-Bar is bit shorter where the vertical portion of T-Bar will be mounted. It means that the bars will not tightly fit because of gap. To set them properly, the width of vertical portion of T-Bar should smaller.



Agent 2 has got errors in two lines marked ('?') after analyzing the request from Agent 1. According to the degree of intelligence of Agent 2, line consisting of points (x_1, y_3) and (x_3, y_3) should be shorter, and line consisting of points (x_3, y_2) and (x_4, y_2) should be longer to avoid design mismatches.

Scenario 3 – *Negotiation*: Agent 1 receives the message from Agent 2. Agent 1 has sent a counter request to Agent 2 to modify C-Bar instead. Agent 2 becomes agree with the proposal of agent 1 after several stages of negotiation. Therefore, the communication starts for collaborative design.

6. Conclusion and Future Challenges

In this paper, descriptions of architectures of query agent and manipulating agent are given, and two agents are considered for distributed collaborative design. One agent is dealing with T-Bar and another agent is dealing with C-Bar to join them together. A typical square bar consisting of T-Bar and C-Bar is built using "*Point to Point*" notion.

CORBA (Common Object Request Broker Architecture) is incorporating because it is a standard for structuring OOAs (Object-Oriented Applications). ORB (Object Request Broker) of CORBA provides bus for objects to communicate in the system. The intelligent interface in our work shows how C++ functions (i.e., whenever instructed) blends with JAVA.

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Semantic Enterprise, Semantic Web and Ontologies in CE

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Ontology-Based mediation system

Nora MAIZ [1], Omar BOUSSAID and Fadila BENTAYEB
ERIC Laboratory, Lumière Lyon2 University
France

Abstract. Data integration by mediation is more practical then centralized data warehouse when data is not static. The use of ontologies in the mediation allows semantic and structural integration. In this paper, we propose a new mediation system based on a hybrid architecture of ontologies modeled according to *GLAV* (Generalized Local As View) model. Thus, we propose an ascending method for building local and global ontologies, which facilitates the semantic reconciliation between data sources. Moreover, we use OWL (Ontology Web Language) for defining mappings between data sources, and ontologies. We also propose a language to formulate user queries. The query language handles global ontology concepts and local ontologies properties because we assume that the user is expert in its domain. Finally, we propose a query rewriting strategy: queries are decomposed to obtain a set of equivalent subqueries that are sent to the corresponding data sources for execution, and after that recomposed to obtain the final result.

Keywords. Data integration, mediation system, ontology, GLAV, hybrid architecture, mappings, query rewriting

Introduction

Data integration is one of the most important phases in the data warehousing processus. When data passes from heterogenous and autonomous data sources to the data warehouse, several inconsistences and redundancies should be resolved, so that the warehouse is able to provide an integrated and reconciled view of data. Centralized data warehouse is a solution for companies handling static data. However, when data change, this solution becomes not practical. Data integration by mediation can solve this problem because it allows building analysis contexts on the fly.

The global architecture of our system, consists to develop a mediation system based on ontologies, and that, to allow building data cubes on the fly (figure 1). First, it consists in building a set of local ontologies, each one corresponds to a data source, and the global ontology by reconciling all differences between local ontologies and defining mappings between local and global ones, proposing a query language and defining a query rewriting strategy. After that, defining the analysis context (data cube) starting from the result of the user query execution using the mediation system. In this paper, we interest only by the first part, which is the construction of the mediation system using ontologies.

The use of ontologies in the mediation allows a structural and semantic integration. We chose to use the hybrid ontology architecture [1,2], which associates a local ontology

[1]Corresponding Author: Nora MAIZ, ERIC Laboratory, Lumière Lyon2 University
5, avenue Pierre Mendès France 69676, Bron Cedex, France; E-mail: nmaiz@eric.univ-lyon2.fr.

for each data source and a global ontology to define mappings and solve heterogeneity problems between local ones, viewed as the mediator, because it is flexible for updates and there is no need to define mappings between local ontologies. The previous architecture is modeled according to *GLAV* structural model, which maintains independence between data sources and allows to indirectly computing mappings between them.

Moreover, we propose an ascending method starting from the conception of local ontologies, then we use these ontologies to build the global ontology and define mappings between them. The query processing in the model that we adopt is only feasible when queries are expressed in terms of global and local levels. For this reason, we propose a query language and a strategy of query rewriting, which enables to divide a query into several equivalent subqueries. The rewriting strategy guarantees that subqueries will be combined after their execution to obtain a final result.

Our work lies within the scope of a project of Virtual Warehousing of Banking Data in LCL - Le Crédit Lyonnais. The purpose of the project is to manage and improve the decision process in LCL in the direct marketing activities domain. It contains many management applications and databases. The banking data are heterogenous and change much, so the construction of data cubes on the fly is pertinent. Each cube represents a specific analysis context. So, our approach consists in defining a dispositive of mediation, which allows, starting from data sources, to build data cubes using ontologies. We interest here just by the mediator construction.

The remainder of this paper is organized as follows. A state of the art presents the mediation systems using ontologies in section 1. Section 2 presents our approach of creation of various ontologies applied to the data sources of the LCL. Section 3 presents our query language and our strategy of query rewriting. The implementation of our mediator is exposed in section 4. We finish this article by the section 5 which concludes our work and presents the prospects on new generated problems.

1. State of the art

we present in this section an overview of the techniques our proposal relies on, namely those regarding data integration using ontologies. Recently, some methodologies were proposed to support the ontologies development and to set up them in a integration system [3,4]. Three different directions are identified: (1) approaches with only one ontology the case of system SIMS [5], (2) approaches with multiple ontologies as in OBSERVER [6] and (3) hybrid approaches that consist in describing the semantics of each source by its own ontology which is built starting from a global shared vocabulary [7].

The GAV (Global As View) approach [8], which comes from the federated data bases world, consists in defining the global schema according to the data sources to be integrated schemas. The systems according to this approach are: HERMES [9], TSIMMIS [10], and MOMIS [11]. *LAV* (Local As View) approach is the dual approach. It is adopted in the following systems: Razor [12], Internet Softbot [13], Infomaster [14], OBSERVER [6], and PICSEL [8]. The advantages and disadvantages of these two approaches are opposite [8]. According to *LAV* approach, it is very easy to add an information source, which does not have any effect on the global schema. On the other hand, the construction of query's answers is complex, contrary to the construction of answers in a system adopting *GAV* approach which simply consists in replacing the predicates of

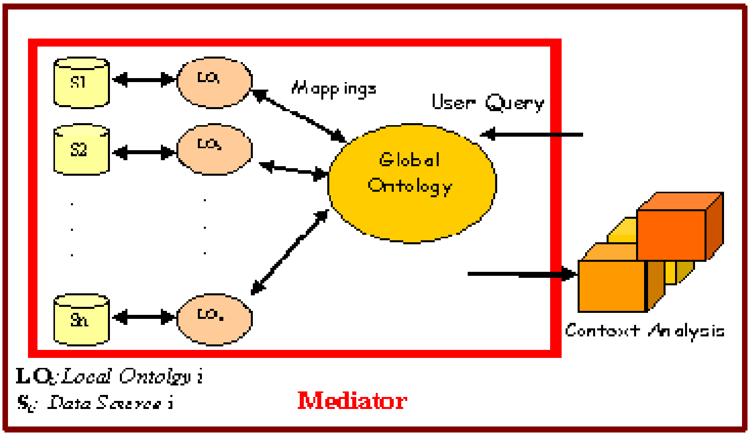

Figure 1. Ontology-based mediation system architecture.

the total diagram of the request by their definition. Finally, *GLAV*(Generalized Local As View)approach, associates views on data sources relations to views on global relations. Views in this model are in the local and the global levels. *GLAV* model is more adapted for distributed data integration environnements since that mapping are more expressive in this model.systems used this model are [15,16]. Other mediators on the semi-structured data having the format of XML documents were developed more recently as (C-Web, Xyleme [17]). Cali et al. [18] proposed a data integration system by mediation in data warehousing based on the definition of the logical and the conceptual levels.

2. Ontology-based Mediation System

2.1. Ontology development approach

In this section, we present our approach for ontology construction using the hybrid architecture modeled according to *GLAV* model. We use *OWL* (Ontology Web Language), for the ontologies description, and for defining mappings between local and global ontologies. In fact, *OWL* is capable of describing data and metadata in order to make ontologies more powerful for the integration task. *OWL* is based on *RDF*(Resource Description Framework), so it gathers the *RDF* description power and the capacity of reasoning.

The approach we propose consists in creating ontologies in an ascending way in order to facilitate the semantic reconciliation between sources. The validation by the expert is crucial. It consists in classifying concepts and solving conflicts. Consequently, our approach is characterized by its precision, the increase of knowledge quality, and the decrease of knowledge reuse complexity.

The process of ontologies development must be particularly performed by the global ontology construction. In fact, this ontology ensures the connection between various lo-

cal ontologies and contains the knowledge for the query formulation and the data warehouse construction.

Three principal phases constitute ontologies construction method:

1. Construction of local ontologies;
2. Construction of a shared vocabulary in the form of a global ontology;
3. Definition of mappings between data sources, local ontologies and global one.

The first phase consists in creating local ontologies. It is composed of two steps: (a) analysis of sources; and (b) the definition of ontology concepts. The first step is a complete analysis of each source independently. The analysis consists in searching primitives used in sources, implicit information, the way of its storage, its significance and its relation with other terms. After that,we define terms which will constitute the ontology hierarchy, their relations and constraints on their use.

The second phase is the extraction of the global ontology starting from various terms used in local ontologies. It contains to steps: (1) local ontologies analysis; and (2) selection of all concepts and solving semantic conflicts. The first step is a complete analysis of local ontologies. Note that, ontologies analysis is easier than that of data sources. After concepts selection, the expert solves all kinds of heterogeneity (naming conflicts, confounding conflicts and/or scaling conflicts) to determine global ontology concepts.

The third phase, which represents the core of the system, consists in defining mappings between the global and local ontologies. The global ontology is built from local ontologies. So, in order to identify the original ontological source of concepts, we use annotations. OWL enables the annotation of concepts and properties according to predefined meta data schema.

Our approach in opposition to [19], deals with the knowledge context (concepts semantic). Consequently, it is characterized by its precision. It also increases the quality of knowledge and especially helps to easily reuse them. In other terms, the global ontology building will be easier since the semantics of the terms are contained in their context (local ontologies).

2.2. *Application to the banking data of the LCL*

2.2.1. *Local ontologies Construction*

In LCL, we have two relational sources, which are heterogeneous because they were developed independently. The first source contains information relating to the collaborators and the marketing demands. A marketing demand is the formulation of a customer for either a particular event or a specific marketing operation. The second data source contains information on people and their profile in the company. Part of the two relational data sources schema is described below:

- Collaborator (IdCollaborator, NameCollaborator);
- MarketingDemand (IdDemand, LIBDemand, IDCollaborator);
- Person (IdPerson, NamePerson);
- Profile (IdProfile, LibProfil, TypeProfil, IdPerson).

Relational tables in OWL are represented by classes (Table 1), relationships between classes are represented by *owl:ObjectProperty* and *owl:-DatatypeProperty*. OWL properties enables to represent various attributes and constraints in the relational schema.

Table 1. Relational tables representation in OWL

Tables	Equivalent OWL
Collaborator	owl:Class rdf:ID="Collaborator
MarketingDemand	owl:Class rdf:ID="MarketingDemand
Person	owl:Class rdf:ID="Person"
Profile	owl:Class rdf:ID="Profile"

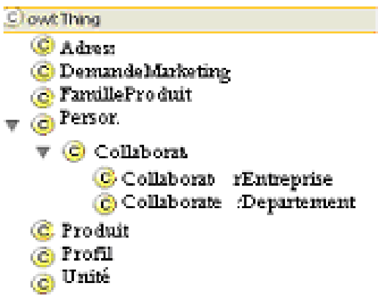

Figure 2. Global Ontology.

They represent attributes by *Datatype*. If the attribute is a primary key, a functional characteristic will be added. In addition, we use *owl:ObjectProperty* to represent foreign keys attributes. Therefore, we obtain two ontologies representing the two relational data sources.

2.2.2. *Global ontology construction*

The construction of the shared vocabulary contains two principal steps: (1) analysis of local ontologies; and (2) the selection of all concepts and the resolution of semantic heterogeneity problems. The first step implies a complete analysis of the previous ontologies, which are built independently. After the selection of concepts, it is necessary to figure out problems of semantic heterogeneity. There are three principal causes behind semantic heterogeneity: confusion conflicts, graduation conflicts, and naming conflicts [20]. Naming conflicts are the most frequent ones. In order to solve them, two solutions are proposed:

- Case of homonyms: we suggest that the two concepts must be renamed on the level of global ontology. These concepts can be generalized by an other concept, which will have in the ontology two subclasses corresponding to these two concepts (see figure 2). For example, concepts "*DepartementCollabor*" and "*CompanyCollaborator*" are homonyms, therefore, they can be generalized in the global ontology by the concept "*Collaborator*", which has two subclasses.
- Case of synonyms: It is necessary at the global ontology to express an equivalence between two synonym concepts. For example "*Collaborator*" and "*Responsible*" for two different sources have the same meaning. So, they are synonym concepts.

2.2.3. Mappings between global ontology and local ontologies

We annotate the concepts of the global ontology with an annotation schema, which contains the following three properties:

- Original local ontology of the annotate concept *(Uri_Local_Ontology)*;
- Responsible agent of this local ontology *Agent_Local_Ontology)*;
- Concept name in local ontology *(Concept_Local_Ontology)*.

3. Query rewriting

After building local and global ontologies, we use their terms and properties to formulate queries.

3.1. Query language

The use of the global ontology as a model for query reformulation is not new. It can be more intuitive for the users. We adopted this alternative since that the user wants to obtain an analysis context as an answer to his query, is an expert in this domain. Our system allows queries to exploit concepts of the global ontology and properties of local ontologies. A basic user query is in the form:

$$Q_i \;=\; \textbf{Concept} \;\Lambda\; \textbf{Property} \;\Lambda\; \textbf{Concept} \;\; or\; only \;\; \textbf{Concept}. \tag{1}$$

The user query is a conjunction of several basic queries:

$$Q \;=\; \wedge_{i=1..n}\, Q_i \tag{2}$$

3.2. Rewriting Strategy

The user query is a conjunction of several subqueries. To obtain a final result, these subqueries must be equivalent semantically. To guarantee this condition, we use our strategy of query rewriting, which for each subquery (concept) of the user query, we selects all candidate concepts from other subqueries. A candidate concept is a concept, which has the same annotation that the used concept. Then, we verify if the used concept is is directly linked to candidate concepts by a property or by a subsumed or a subsuming concept. If there is no link, the used concept is excluded.

- **Example**
  The following query concerns all collaborators having an address in Lyon with a certain profile:
  $(Collaborator(x)\ \Lambda\ hasAddress(x,y)\ \Lambda\ Address(y))\Lambda$
  $(Address(z)\ \Lambda\ hasAsTown(z, "Lyon"))\Lambda$
  $(Profile(p))$.
  The mediator breaks up it into three subqueries. The two first are linked by the concept *Address*, so, they are sent to the corresponding sources to be executed because they can be recomposed by a classic join. However, the third subquery is not linked with the two previous subqueries. The mediator must find a link between

Profile concept and concepts of the previous subqueries, which are *Collaborator* and *adress*. If there is no link, it excludes this concept. The link is a property, which links directly these concepts with *Profile* concept. It can be also a property links *Profile* concept to another equivalent concept, subsumed or subsuming one of the two previous concepts, *Collaborator* or *Address*. In our case, the concept *Person* is the concept subsuming *Collaborator*, and it has a link with *Profile*. The mediator must thus rewrite the third subquery "*Profile (p)* " into :
"$Person(r) \Lambda HasProfile(r, p) \Lambda Profile(p)$". It must add in its table of correspondence that *"Collaborator"* of the first subquery corresponds to *"Person"*of the third subquery.

4. Implementation

To validate our approach, we develop an environment that implements our architecture of mediation. Our system manages data sources independence and their distributivity. It also manages the interaction between global ontology and local ones at the time of query creation. Multi Agents Systems *(MAS)* are more adapted for distributed and cooperate environments.

Our environment is distinguished from the existing integration systems by mediation by the fact that it enables to express descriptions of sources using the recent recommendation *W3C* for the ontologies description, which is *OWL*. It offers very interesting possibilities of descriptions and reasoning. Our

objective is also to combine the power of expression and description of language *OWL* with the aspect communicating and co-operative Systems Multi Agents *(MAS)*.

The mediator is an agent that communicates with the other agents and has global ontology. The other agents are the sources agents. The process of creation or rewriting of request in our environment is done by a dialogue between the agent mediator and the other agents. For the development of this environment, we used a certain number of tools: the ontology editor *Protégé2000*, the framework *JADE* for agents, the framework *Jena* for OWL-ontologies handling. *Jena* is a project of free source code developed at HP for the semantic Web. This framework offers us many advantages: it enables to have a uniform access for various ontologies because all information is stored in a *Jena* model. For the reasoning on OWL-ontologies, we use the free arguer *Pellet*, which allows to reason on the terminological part. The queries interface is presented in the form of a Java Web application based on the framework Struts.

5. Conclusion and future work

In this paper, we have proposed a new approach of data sources integration based on ontologies in data warehousing environment. Our approach is based on hybrid architecture, using a global ontology for the mediator and local ontologies for the sources. It is important to create global ontology starting from local ontologies, because this facilitates and improves the resolution of semantic heterogeneity between the sources ontologies. We defined a method of ontologies construction, a language which guarantees the correct treatment of queries, by allowing their expression in terms of global and local ontologies.

We also proposed a strategy of query rewriting which allows ensuring the query coherence, by guaranteeing a global answer. We applied our approach of ontologies creation on the relational sources of the *LCL*. These ontologies are used in our system of integration, and were useful in the phase of creation and rewriting of queries. The query language and the method of query rewriting proposed were validated by an implementation in the system *INMEA*.

Various perspectives are considered. Initially, completing the implementation by developing other agents responsible of ontologies and extending it to other relational sources. Then the adaptation of the system to the various sources of information. It will be necessary to automatize the ontologies conception method. It is necessary to study the algorithm complexity and to reexamine the rewriting strategy by taking into account decisional queries. In addition, the generation of a context of analysis must be considered. This second part of the project of Virtual Storage of Banking Data poses many problems: the choice of the model which contains the repatriated data, the meta model to have the data cube, materialization of the data cube, the specification of the rules of calculation to be carried out within the data cubes, and finally, the capitalization and the representation of knowledge obtained by analysis and to reinsert it in the process of virtual data warehousing. Thus it is necessary to be concentrated on the problem of queries approximation in order to always obtain the data necessary and useful to the analysis.

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LCA and LCC Data Semantics Sharing across Product Lifecycle Processes

Q.Z. YANG [a, *], C.Y. MIAO [b], Y. ZHANG [c] and R. GAY [b]
[a] *Singapore Institute of Manufacturing Technology, Singapore*
[b] *Nanyang Technological University, Singapore*
[c] *Computing and Information Systems, Stansfield College, Singapore*

Abstract. Product sustainability approaches, such as life cycle assessment (LCA) and life cycle costing (LCC), are becoming increasingly critical to influence product decisions for all lifecycle stages. However, LCA and LCC methods must be integrated into the product lifecycle processes for sharing their data semantics with other applications in order to support decisions in the technical, ecological and economic aspects of products. Semantics sharing has raised big challenges in understanding and interpreting the intended meaning of LCA, LCC and other product data. This paper presents an ontology-driven, standard-based approach to the explicit capture and reuse of product data semantics for heterogeneous information sharing across lifecycle processes in computer aided design, quality assurance, LCA and LCC analysis, and product development process management. The approach incorporates object-based product data modeling, interoperability standardization, and ontology engineering to address the product data semantics sharing issues. A software implementation of the approach with a use scenario is also discussed in the paper.

Keyword. Product lifecycle processes, data semantics, heterogeneous information sharing.

Introduction

The lifecycle of a product spans many stages from early product concept, through design, manufacturing, distribution, use and maintenance, eventually to the end of the product life. Numerous computer-supported applications are employed in each lifecycle stage. For example, TRIZ analytical tools [1] are used during the innovative product concept stage; CAD and CAE packages for product design and analysis; FMEA [2] and QFD [3] tools for improving quality and performance of product development; LCA [4, 5] and LCC [5] applications for product lifecycle ecological and economic impact analyses; and project management systems for planning and coordinating product development activities, resources, and milestones. These systems and tools need to generate, manipulate, and use the lifecycle oriented information across application domains. Having interoperable product information, with explicit data semantics in context, shared throughout the heterogeneous lifecycle processes is therefore becoming more and more important in product lifecycle management towards semantic interoperability.

[*] Corresponding author: QZ YANG, Singapore Institute of Manufacturing Technology, 71 Nanyang Drive, Singapore 638075; E-mail: qyang@simtech.a-star.edu.sg.

A major challenge in efficient product information sharing in an open environment is the lack of explicit semantics and contexts in the digital content to be shared across lifecycle processes. Substantial difficulties in capturing, understanding, interpreting, and consistently using product semantics arise due to:

- The domain-specific lifecycle applications, such as CAD, QFD, LCA or LCC, are often developed independently without the prior intent for integration and interoperation with other systems;
- Each lifecycle process/application uses proprietary information models with different abstraction strategies, representation schemas, and data formats;
- Most of the underlying information models formalize their data meanings, terminologies, and background knowledge implicitly; and
- Semantics are evolving over time, and meanings of digital data are context dependent.

All these challenges above require new developments of methods, models and tools to make data semantics explicit, context-aware, and sharable across product lifecycle processes. Among others, the interoperability standardization technology plays an important role in product information exchange and sharing. In the standardization approach, schema-level specifications, such as STEP [6] Application Protocols or PSL-XML [7] schemas, are defined to provide commonly agreed sets of labels, entity definitions and relationships for interchanging and sharing heterogeneous product information. However, the data meanings of standards are often implicitly encoded in the structures of their syntax or in the schemas of their data models. It is very difficult to consistently interpret, understand, and implement these implicit data semantics across application domains and lifecycle processes.

Another approach to the product semantics sharing among lifecycle processes is based on ontology engineering, in which commonly agreed ontologies are defined to formally and explicitly capture the data semantics in particular contexts. Compared with the standard-based approach, the ontology-based approach is more suitable for use in non-restricted domains and heterogeneous environments [9].

An ontology-driven, STEP-based approach is proposed in the paper, which incorporates interoperability standardization and ontology engineering to facilitate the data semantics sharing among heterogeneous product lifecycle applications and processes.

1. Concepts and technologies

1.1. Product models

Product data semantics refer to the meanings of digital product data. Data meanings are captured in product models. In the current research, different types of product models have been developed. These include the supplementary information models, STEP-compliant product data models, product development process models, and product lifecycle performance models for quality, cost, and environment impact assessment. These models are used for capturing and sharing product datasets and their semantics in lifecycle processes of CAD, quality assurance [8], LCA and LCC analysis [11]; and product development process management [12].

1.2. Interoperability standards

The main standard for interoperation and integration of product lifecycle processes is ISO10303 STEP [6]. STEP aims to provide an open, neutral product information representation and exchange mechanism for products throughout their lifecycles. Using the EXPRESS [10] information modeling language and STEP integrated resources, the STEP community has developed more than 40 STEP Application Protocols (AP) to date for different lifecycle application domains. Some STEP APs, such as AP203, AP210 and AP214 have been implemented in commercial CAD systems to provide the capabilities for importing and exporting STEP files. The downstream STEP-compliant applications will then use the neutral STEP files for product data exchange and sharing.

1.3. Ontologies

Ontologies represent formal, explicit and shared understanding about application semantics, domain concepts and their relationships. In particular, engineering ontologies are often used to describe and capture the product semantics for sharing of heterogeneous information, for integration of distributed engineering knowledge services [13], and for knowledge management and sharing [14]. Ontologies can be distinguished into two categories: logic-based and non-logic-based, depending on whether or not logical axioms and definitions are used in ontologies. Typically a logic-based ontology explicitly specifies the semantics of terminologies through ontological definitions and axioms in a formal language such as the Web Ontology Language (OWL) [15]. The ontological definitions build a common understanding about terms and relations, while the axioms enable reasoning, mapping and matching of them to admit or reject interpretations of terms and concepts. Non-logic-based ontologies, on the other hand, specify the meanings of terms by fixing interpretations with respect to clearly defined contextual constraints. Product data standards such as STEP are often considered as non-logical ontologies.

In this research, a hybrid approach integrating both the standard-based and logic-based strategies is used for semantics sharing across product lifecycle processes of CAD, quality assurance, LCA, LCC, and product development process management. The detailed methodology is elaborated in the next section.

2. A semantics sharing approach

2.1. Product semantics capturing in supplementary information models

The *supplementary information* is defined, in the context of this paper, as the additional product information described with explicit semantic definitions and embedded in CAD models. The supplementary information includes semantic properties, entity types, object behaviors, external reference links, interdisciplinary relationships, and so on. These additional information sets are modeled, attached to and updated with the CAD objects, so that they would be able to support the product information and semantics needs from not only CAD but also other product lifecycle processes. For the supplementary information, it is essential to ensure that the information carries unambiguous semantics, understandable and interpretable by multi-disciplinary software applications. To this end, the following modeling method is developed.

In this method, the traditional CAD objects generated from a CAD system are extended with the supplementary information. The implicit data semantics from CAD models, LCA/LCC models, or other application-specific models are made explicit and captured in a set of entity type definitions, including the entity property and entity behavior definitions, so that the extended CAD objects can carry not only geometric representations and design characteristics from CAD systems, but also semantic instantiations from entity type definitions. The entity types describe the object-based product supplementary data and precisely represent the intended semantics of these data. An entity type is defined by attributes and contextual constraints. The following expression gives an example for an entity property definition with five attributes and two contextual constraints.

<PropertyName, Description, Value[>=0], MeasuredUnit[Enum(KG, MJ, Dollar)], RefNo> (1)

Using the entity property definition in Expression (1) as a template, property objects can be instantiated. Table 1 shows a set of property objects instantiated. The objects are used for the calculation of product LCA/LCC in the manufacturing stage.

Table 1. Property objects instantiated for LCA/LCC calculation

PropertyName	Description	Value	MeasuredUnit	RefNo
Mass	Mass of a product.	0.8	KG	Lca001
Energy	Total Energy spent on Manufacturing processes.	325	MJ	Lca011
Cost	Production cost.	65	Dollar	Lca012

Similarly, the entity behavior definitions can also be modeled and the behavior objects instantiated. Through the use of property objects and behavior objects, together with their semantic definitions in entity properties and entity behaviors, meanings of the supplementary information are captured in object-based representations, which make the product supplementary information understandable among disciplines. However to make them interoperable across disciplinary applications, STEP and its extensions are required.

2.2. STEP-compliant data model development

The standard STEP schemas need to be extended with property definitions to hold the supplementary information sets. This study uses the subtyping extension mechanism for such extensions, in which new entity definitions are created as subtypes of an existing STEP entity. The extended entities are then used, for example, as relationship entities to connect the supplementary entity definitions to those entities already existing in the STEP product models. By using this mechanism, the STEP extension properties are modeled. For example, a single valued property, as an extended entity of STEP AP203, can be defined as follows:

<Name, Description, NominalValue, Unit> (2)

The extended entity definition in Expression (2), together with other STEP extension definitions will be instantiated with the supplementary information to form a STEP AP203 compliant product data model. However, before any instantiation, the semantic mapping from supplementary entity definitions to STEP extension definitions has to be performed.

2.3. Mapping between semantic models and STEP models

The semantic mapping makes the supplementary information definitions in Section 2.1 compatible with the extended STEP entity definitions in Section 2.2. Semantically equivalent components in the supplementary information and STEP entity definitions are identified and compared. The semantic mapping knowledge is then established at both the entity and attribute levels. Table 2 below shows an example for entity property mapping knowledge from the supplementary information definition in Expression (1) to the STEP extension property definition in Expression (2).

Table 2. Example of mapping knowledge

Supplementary Information Definition	**Extended STEP Property Definition**	**Mapping Knowledge**
EntityProperty.PropertyName	StepProperty.Name	(PropertyName, NameString, *is-a*) (NameString, Name, *part-of*)
EntityProperty.Description	StepProperty.Description	(Description, Description, *equal*)
EntityProperty.Value	StepProperty.NominalValue	(Value, Real, *type*) (Real, SimpleValue, *part-of*) (SimpleValue, NominalValue, *is-a*)
EntityProperty.MeasuredUnit	StepProperty.Unit	(MeasuredUnit, DerivedUnit, *EnumType*) (DerivedUnit, Unit, *is-a*)
EntityProperty.RefNo	StepProperty.Name	(RefNo, Name, *part-of*)

2.4. Classification of common vocabulary

Product lifecycle processes involve multi-functional disciplines with various viewpoints, goals, priorities, and backgrounds. Different terms may be used for representing the similar concepts or a single term for different concepts. Even, in some situations, concepts may not be explicitly defined or defined with implicit assumptions. A collection of common vocabulary agreed by collaborating parties would be beneficial in achieving a common and explicit naming approach to shared use in different disciplines. A vocabulary library has been developed to classify and store the sharable terminologies together with their meanings used in the product development domain. The terminologies are mainly used for naming properties, CAD behaviors, object relationships and constraints of the supplementary information. Figure 1 shows a part of the vocabulary classified.

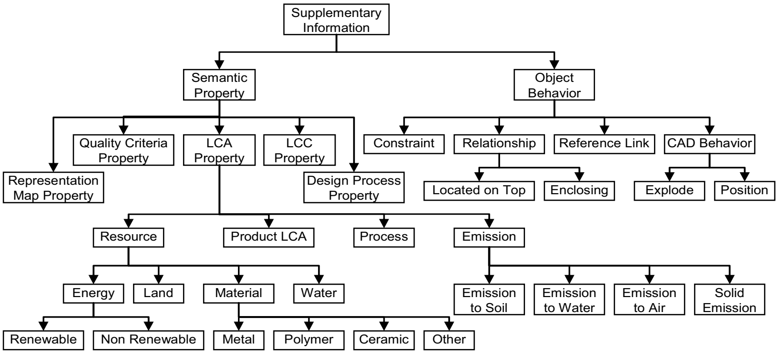

Figure 1. Partial vocabulary taxonomy

2.5. Ontology modeling

Based on the common vocabulary built in Section 2.4, a shared reference ontology in OWL has been defined to provide an integrated conceptual knowledge model for sharing product supplementary information and semantics in heterogeneous applications of CAD, quality assurance, LCA and LCC, etc. Figure 2 shows a segment of the ontology for a definition of the concept "*ProductLCA*" in Figure 1.

```
<owl:Class rdf:ID="ProductLCA">
  <rdfs:subClassOf rdf:resource="#LcaProperty"/>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#refNo"/>
      <owl:cardinality rdf:datatype="&xsd;nonNegativeInteger">1</owl:cardinality>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
<owl:DatatypeProperty rdf:ID="propertyName">
    <rdfs:domain rdf:resource="#ProductLCA"/>
    <rdfs:range rdf:resource="&xsd;string"/>
</owl:DatatypeProperty>
<owl:DatatypeProperty rdf:ID="description">
    <rdfs:domain rdf:resource="#ProductLCA"/>
    <rdfs:range rdf:resource="&xsd;string"/>
</owl:DatatypeProperty>
<owl:DatatypeProperty rdf:ID="value">
    <rdfs:domain rdf:resource="#ProductLCA"/>
    <rdfs:range rdf:resource="&xsd;float"/>
</owl:DatatypeProperty>
<owl:DatatypeProperty rdf:ID="refNo">
    <rdfs:domain rdf:resource="#ProductLCA"/>
    <rdfs:range rdf:resource="&xsd;string"/>
</owl:DatatypeProperty>
<owl:ObjectProperty rdf:ID="hasUnit">
    <rdfs:domain rdf:resource="#ProductLCA"/>
    <rdfs:range rdf:resource="#UnitMeasures"/>
</owl:ObjectProperty>
<owl:Class rdf:ID="UnitMeasures">
     <owl:oneOf rdf:parseType="Collection">
       <owl:Thing rdf:about="#KG"/>
       <owl:Thing rdf:about="#MJ"/>
       <owl:Thing rdf:about="#Dollar"/>
     </owl:oneOf>
</owl:Class>
```

Figure 2. OWL code for a definition of *ProductLCA* concept

An OWL property (i.e. ObjectProperty or DatatypeProperty in Figure 2) is a binary relation to relate an OWL class to another one, or to RDF literals and XML Schema datatypes. For example, the *"hasUnit"* ObjectProperty relates the *ProductLCA* class to the *UnitMeasures* class; and both the *"propertyName"* and "*description"* DatatypeProperty relate the *ProductLCA* class to the *string* datatype of the XML Schema. The *domain* and *range* pairs in Figure 2 restrict these relations. Another OWL restriction used is *cardinality* to constrain the range of *refNo* in a specific context.

Described by these formal, explicit and rich semantics, the domain concept of *ProductLCA*, its properties and relationships with other concepts can be queried, reasoned or mapped to support the product semantics sharing across lifecycle processes.

3. Prototype implementation and use scenario

3.1. Software prototype system

The semantic sharing approach in Section 2 has been implemented in a software prototype. It consists of a design Object Creation Wizard for generating lifecycle

oriented design objects embedded with supplementary data semantics; an Interfacing tool for extracting quality and process related data from their native models; and a LCA/LCC Integration tool for processing the quantified impact results from LCA and LCC systems and instantiating the definitions of the LCA/LCC semantic properties.

3.2. Use scenario: LCA data semantics capturing and sharing

This scenario demonstrates the creation of CAD design objects captured with data semantics from the LCA property supplements. The AutoCAD system is used for modeling geometries of these design objects, together with the Object Creation Wizard for defining and embedding supplementary data semantics into the CAD models. An *oil filter* is taken as a modeling example in this scenario.

The 3D CAD representations are modeled by AutoCAD. They are packed with multi-view blocks to describe the geometry of the designed objects. To specify and capture the LCA supplementary information in CAD models, the Object Creation Wizard is invoked from within the AutoCAD environment.

The Wizard automatically extracts the relevant design characteristics from the *filter* CAD model to instantiate the 3D representation map definitions according to the reference ontology. As the LCA data is not available from the CAD model, the Wizard provides GUIs to allow new parameter entries from users or from external programs. All input data will be evaluated by contextual constraint algorithms of the Wizard. Through mapping and annotating the embedded information semantics, the Wizard generates STEP files by invoking STEP export facilities of the CAD system. An XML instance file for the *filter* is generated to annotate the data meaning according to the reference ontology in Section 2.5. Both STEP and XML files, together with the filter CAD model extended with the LCA supplementary information, will be submitted to a design object server for sharing with other applications.

During the semantics sharing process, the meaning of the embedded supplementary information are queried, inferred and reused to support interoperation of multi-disciplinary applications. For example, a testing engineer can download the XML instance file of the *filter* for sharing the *Mass* instance of the *ProductLCA* for his testing system (Figure 3).

```
<ProductLCA rdf:ID=”OilFilter_Mass”>
    <propertyName rdf:datatype=”&xsd;string”>Mass</propertyName>
    <description rdf:datatype=”&xsd;string”>Mass of an oil filter</description>
    <value rdf:datatype=”&xsd;float”>0.8</value>
    <refNo rdf:datatype=”&xsd;string”>Lca001</refNo>
    <hasUnit rds:resource=”#KG”/>
</ProductLCA>
```

Figure 3. OWL instance for *Mass*

The testing application system understands the meaning of terminologies used in Figure 3 by referring to the terminology definitions in Section 2. The logical relations of the terminologies are queried based on the semantic descriptions in the reference ontology in Figure 2. For example, by querying the OWL instance for *OilFilter_Mass* in Figure 3, the quality Interfacing tool retrieves the semantics of the concept *ProductLCA*, such as its OWL datatype properties (*owl:DatatypeProperty* in Figure 2)

for *propertyName*, *description*, *value* and *refNo*, as well as the OWL object property (*owl:ObjectProperty* in Figure 2) for *hasUnit*. So, the testing system can interpret and reuse the inferred data meaning "mass of the oil filter being 0.8 KG". In this way, the data semantics from different product models are shared across heterogeneous systems explicitly and flexibly.

4. Conclusion

An ontology-driven, STEP-based approach has been proposed for explicitly specifying, capturing, interpreting, and reusing the product semantics to facilitate heterogeneous information sharing across lifecycle processes. To demonstrate the usability of the approach, a prototype has been developed for the generation, management, and sharing of semantics-rich design objects. The prototype is tested with case studies for capturing and sharing supplementary information with explicit LCA data semantics. The application scenario shows that the design objects modeled with this approach and encapsulated with the interoperable semantic properties could provide multi-disciplinary applications with understandable, transferable and sharable product information. The future efforts will be focused on ontology reasoning and matching issues to support more effective sharing of product semantics across heterogeneous lifecycle processes.

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Managing Concurrent Engineering Design Processes and Associated Knowledge

Richard SOHNIUS[a], Vadim ERMOLAYEV[b], Eyck JENTZSCH[a], Natalya KEBERLE[b], Wolf-Ekkehard MATZKE[a], Vladimir SAMOYLOV[c]

[a] *Cadence Design Systems, GmbH, Mozart str., 2, 85622, Feldkirchen, Germany*
[b] *Zaporozhye National Univ., 66, Zhukovskogo st., 69063, Zaporozhye, Ukraine*
[c] SPIIRAS, 39, 14-th Liniya, St. Petersburg, 199178, Russia

Abstract. This paper presents our work in collecting and formalizing data about dynamic engineering design processes in microelectronics design projects. The paper reports on our experience in evaluating the design process knowledge acquisition routine by applying it to the real industrial project of Cadence Design Systems, GmbH. The methodology is based on the usage of the ontologies developed in the PSI project. Beside the actual process of formalizing the processes it especially focuses on capturing information about the concurrency among activities.

Keywords. Concurrent activities, Dynamic Engineering Design Process, ontology, agent, multi-agent system, knowledge acquisition, microelectronics

1. Introduction

It is well known that the design of microelectronic devices gets more and more complex[1] and to keep the design time and cost of such devices in reasonable boundaries, the productivity must be increased. Cadence Design Systems GmbH started the *Performance Simulation Initiative* (PSI) to help customers in finding and improving the weak spots in their design processes [1] and thereby increasing productivity. The approach is to examine *dynamic engineering design processes* (DEDPs) [2] by acquiring knowledge about them using a family of OWL[2] ontologies [2][3], and to employ the *multi-agent system* approach to simulate them [4]. The simulation results can then be used to assess past projects and to analyze how to optimize a given design system for future projects.

In this paper we focus on the methodology of acquiring and formalizing the information about DEDPs required for simulation using the PSI Ontologies. The paper is structured as follows: Section 2 surveys the related work in this field; Section 3 describes the general properties of design processes; Section 4 gives an overview of the ontologies used; Section 5 presents the different aspects of concurrency encountered;

[1] Moore's law: every 18 months the processing power (of the product) doubles while cost holds constant.
[2] Web Ontology Language (OWL): http://www.w3.org/TR/owl-ref/

Section 6 explains the formalization process based on an example test case; Section 7 contains the conclusions and the plans for future work.

2. Related Work

The mainstream of formal business process modeling and engineering today is using PSL [5], PDL [6] or their extensions. Unfortunately, these formal flow modeling frameworks do not fully allow breaking down the diversity of the processes encountered in real life. This diversity may be characterized for example by Sandewall's taxonomy [7] providing the basic features of the processes. This classification embraces highly predictable, normal, manufacturing processes at one side and stochastic ("*surprising*" [3]), structurally ramified, time-bound processes characteristic for design domain, on the other side of the spectrum.

In our search for the proper upper-level ontological paradigm for DEDP modeling we examined the SUMO and DOLCE [8] ontologies as candidates for the formal description framework. In DOLCE a process is the sub-category of a perdurant. Perdurants also comprise events, phenomena, activities, and states. The semantics of a DEDP in our framework is aligned with DOLCE in this sense. However, we consider DEDPs to be the aggregations of the simpler occurrences: sub-processes, events, states, activities. As in DOLCE we assume that subjects and objects are not parts of processes, but rather participate in them or are transformed by them.

The conceptual framework and the PSI family of ontologies [3] used to model DEDPs are the follow-up of our results published in [2]. The DEDP modeling framework in its part of organizational and actor-related knowledge representation is based on the frameworks [9][10][11], extends them by incorporation of roles, abilities, actors, dynamic teams of actors, and its binds to the engineering design domain. In the part of process modeling PSI bases its approach on [12], [13], [14]. One advancement of the PSI ontologies family is the classification of the concurrency types as the co-execution types [3]: *sequential, partially overlapping at start (end), inner overlapping, parallel.*

3. Concurrent Engineering Design Processes in Microelectronics

The processes of designing microelectronic devices tend to be executed as parallelly as possible. The design tasks are too time-consuming to be executed in sequence since time to market is one of the critical aspects of the process. Especially in the consumer electronic space, certain deadlines (e.g. Christmas) must be met to survive in business. In order to be able to exploit concurrency where possible, it is essential to model the dependencies between tasks as detailed as possible.

Another important aspect of these design processes is the lack of predictability. No two devices are designed exactly the same. Therefore, the simulation can only give an approximate estimation of a process flow and the time it requires. As a result, it has to be able to adapt as the dynamic system develops. We use DEDP-MAS [4] to simulate human-like behaviour and to provide the required flexibility.

[3] A process is considered "surprising" if it is allowed that a *surprising* or *exogenous* event may cause a change that is not anticipated by the process script [7].

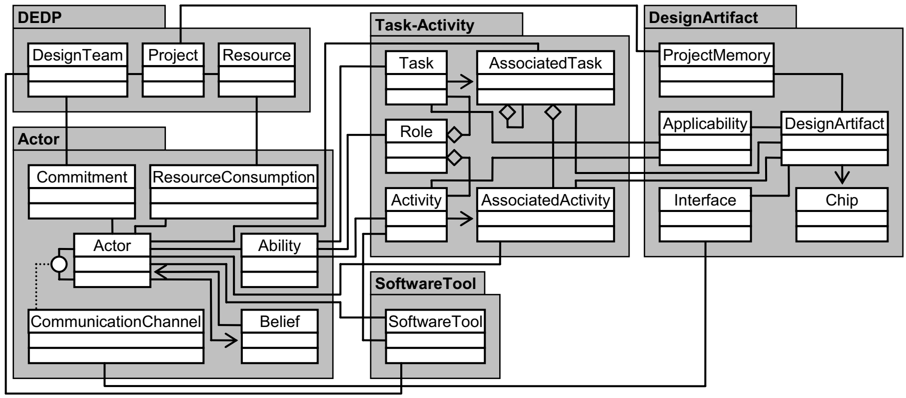

Figure 1. PSI Ontology overview

According to Sandewall's taxonomy [7] a DEDP may be considered a *discrete, branching, structurally ramified, concurrent, surprising, equinormal, hierarchical, time-* and *memory-bound* process with *delayed* effects. This combination of the features makes DEDP modeling a challenging task. The starting point for our modeling framework was the observation that an arbitrary engineering design process is the configuration of the following basic building blocks: a goal (the state of affairs to be reached); an action; an object to apply actions to; a subject who (or which, if unanimated) applies actions to objects; an instrument to be used by a subject to execute actions; and an environment in which the process occurs. This structure at the first glance resembles the one of PDI (Process Definition Interface [6]).

4. Expressing DEDP Knowledge Using PSI Ontologies

The PSI family of ontologies comprises five tightly linked ontologies which in UML representation are grouped in separate packages: the Actor Ontology (a subject), the DEDP Ontology (an environment), the Task-Activity Ontology (an action), the Software Tool Ontology (an instrument), and the Design Artifact Ontology (a goal and an object). The classes shown within the packages in Figure 1 identify the major concepts of the respective ontology [3].

The instances created using the ontologies are grouped by their level of abstraction. The most abstract level is the knowledge base. It contains the information on the types of design artifacts that can exist and the activities that can be executed on these design artifacts. This level is also considered common knowledge and is the same for all projects examined. The next less abstract level is the project definition. It comprises all the knowledge and data required to simulate the project: the structure of the design artifact, the design team, its members and their skills, the available resources, the desired project output and the time frame. Finally, the last level is the project plan. It contains all the activities executed (or to be executed), their schedule and the assignment of the designers and the resources to them.

One of the facets of activity descriptions used in PSI (unlike PSL [5] or TOVE [9]) is the description using the design artifact input and output representations. An activity

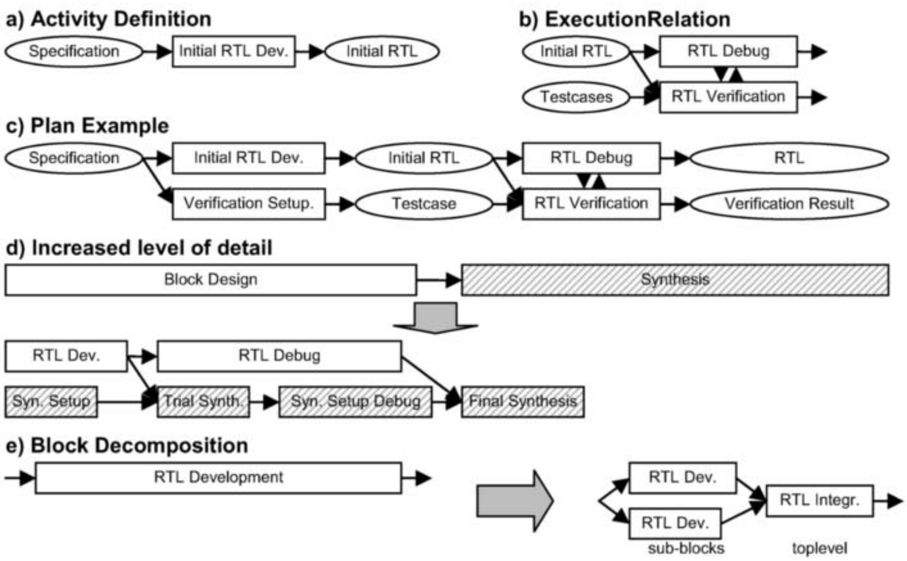

Figure 2. Activity representation and concurrency

transforms a design artifact from one representation to another. For example *Initial RTL*[4] *Development* transforms a functional block in the representation *Specification* to the representation *Initial RTL* (see Figure 2a). Therefore, the simulation does not rely on predefined plans but can link activities by the representations of their inputs and outputs (see Figure 2c) to build a graph which shows every possible way from the initial input representations to the target output representations and can then choose the optimal one. Activities have a property *difficulty* which is used to estimate the required design time. The result of the linking of input representations to output representations is called the IO-chain.

Additionally, the appearance of an activity is constrained by its applicability which describes to which type of a design artifact the activity can be applied. You cannot for example apply *Initial RTL Development* to an analog block.

Finally, we model co-activities by introducing an *ExecutionRelation* which allows restricting the co-execution type between two activities. The problem is that some activities exchange information and therefore must be executed (partially) in parallel. For example *RTL Debug* and *RTL Verification* need to be executed in parallel as the verification requires the debugged RTL and the debugging requires the verification results (see Figure 2b).

5. Concurrency

In a DEDP the activities which do not depend on each other are executed concurrently in order to reduce the total development time. Additional concurrency can be gained by

[4] RTL (Register Transfer Level), functional description of a digital block in terms of logical and sequential equations.

accounting more process details (Section 5.1) or by decomposition of blocks (Section 5.2).

5.1. Improving concurrency using finer-grained process model (knowledge base)

One of the methods to allow for increasing the process concurrency is by increasing the level of detail in the knowledge base. If, at the knowledge base development stage, it is found out that a meaningful action viewed as an activity can be represented as the composition of several other activities, the knowledge base should be adjusted accordingly. Some of these activities may be executed concurrently and their introduction may therefore add to the concurrency factor. For example, at an early modeling stage *Block Design* and *Synthesis* tasks could be seen as coarse activities which have to be executed in sequence due to their input/output representations. When the knowledge base is refined both are modeled by the compositions of several activities (Figure 2d). After that both tasks can be executed partially in parallel.

Since the majority of design tasks are typical in the industry branch the knowledge base appears to be a valuable knowledge asset which may be efficiently reused and transferred.

5.2. Concurrency by block decomposition

Another way to gain improved concurrency is to perform an activity on each sub-block and integrate the results instead of performing the activity on the whole design. This also reduces the difficulty of each activity compared to the original one as only the complexity of the associated sub-block impacts each design activity and the integration activity depends only on the interconnection of the sub-blocks. Figure 2e shows this method using the example of *RTL Development*.

6. The Test Cases: Knowledge Acquisition Using PSI Ontologies

The ontologies were initially evaluated with different test cases. At the beginning simplified artificial data was used (e.g. [15]). The simulation of DEDPs based on these simplified initial test cases has been reported in [4]. In this paper we shall report on the follow-up work with one of the real projects run at Cadence Design Systems, GmbH.

The knowledge acquisition and DEDP modeling scheme for real projects is as outlined in Figure 3. The project knowledge is first homogenized and formalized. Then the project definition is extracted. After that the acquired knowledge is used to re-plan and re-schedule the project by simulations. These results are then compared to the original plan and schedule developed by the project manager manually. In this paper we describe the left branch of the routine: starting from the raw sources and ending up by the project definition (steps 1-3 in Figure 3).

6.1. The Test Case

The test case described here is a real project which created an MMC/SD[5] host controller Soft IP[6]. The available input consists of the project plan in the form of a

[5] MMC (Multi Media Card) / SD (Secure Digital Card), flash memory card formats.

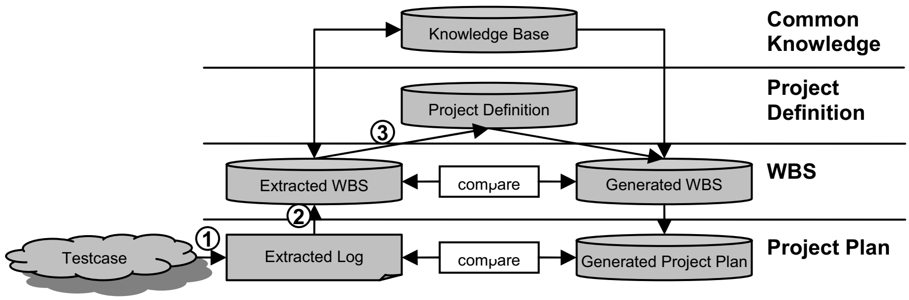

Figure 3. Test case knowledge acquisition and usage

GANTT-diagram with resource assignments, a block-diagram and a verbal description of the designers by the project leader. The project was chosen because it is small enough to be formalized relatively quickly and still contains the typical pitfalls (see Sections 6.2, 6.3) which were not present in the initial simplified test cases. In detail, it contains 4 digital blocks and 34 tasks executed by 3 designers. The resulting WBS had 30 activities.

6.2. Formalizing the Design Process Log

The first step in formalizing the project knowledge was the extraction of the required information from the sources and bringing it to a homogenous representation – a spreadsheet was used to hold the data. This is the step 1 shown in Figure 3. The main problem at this step is to associate each task with one particular block of the design.

The resulting process log was incomplete and ambiguous. In the available knowledge sources, several smaller tasks had been omitted or grouped together in the project plan to keep the diagram clearer to the manager whereas the bigger ones were split to show the different facets of a task. There was for example no explicit verification of one of the functional blocks (*register file*) as it was always verified in conjunction with the other blocks. On the other hand, there were several test case development tasks for the command path - one per command mode. This was mainly because the project was structured differently than intended by the ontology and the model. The project leader had grouped the tasks only by their similarity without respect to the block structure while the model organizes tasks by both aspects and requires a strict association of tasks to blocks.

6.3. WBS Extraction

The next step was the extraction of a coherent WBS from the log (Figure 3 step 2). This required the logged tasks to be mapped to activities described in the knowledge base (Figure 4). If the project contains tasks which cannot be represented with the activities in the knowledge base, the knowledge base must be extended. In the given case, activities for FPGA-emulation and coverage analysis were added.

[6] Soft IP (intellectual property) is a predefined functional block which is incorporated in other designs. In contrast to Hard IP which comes in the form of layout data, Soft IP is delivered as a functional description which still needs to be mapped to a specific silicon technology.

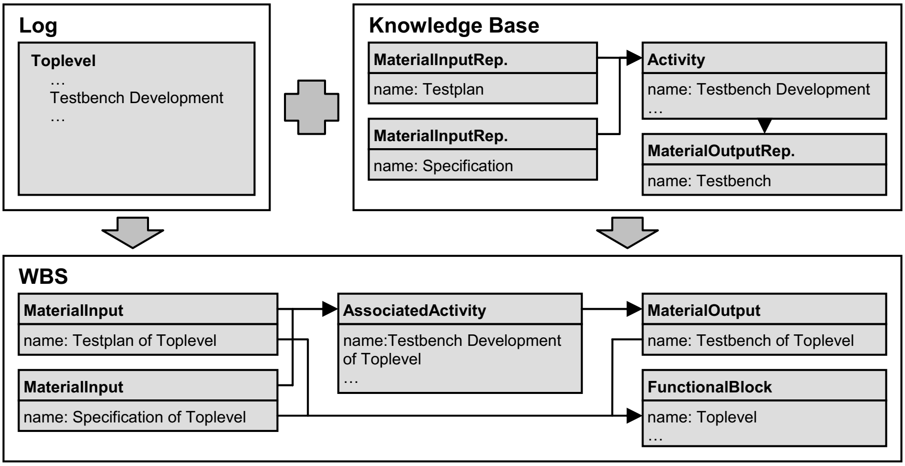

Figure 4. Task mapping example for Testbench Development

This step required some tasks to be split and others to be merged to remove simplifications in the original project plan. Consequently, the tasks which had been omitted in the project plan were introduced at this step to complete the IO-chain. Finally, the missing data had to be supplemented. This work normally requires the profound knowledge of the domain and the project itself and is best done with the help of the project leader or the designer working on the particular part of the project. In this particular case the project leader was available as domain expert.

To reuse the previous example, the test case development tasks for the command path were merged into one activity..The example of splitting a task was the synthesis. Due to the simplicity of the design the source project plan did not further refine the synthesis task. But the knowledge base suggested the composition of the four activities instead - '*Synthesis Setup*', '*Trial Synthesis*', '*Synthesis Setup Debug*' and '*Final Synthesis*'. Thus, the original task was split in four activities. Finally, small verification activities applied to the register file were introduced to complete the IO-chain.

6.4. Extracting the Project Definition

This is the last step in the knowledge acquisition routine (Figure 3 step 3). Acquiring project data like starting date, end date and required output is straight-forward as is the description of block structure. The assessment and modeling of designers' abilities and the complexity of blocks is a rather difficult topic and will be a major part of our future research. For now we are working with the simplified model and the acquisition is currently relying on the judgement of the designers only.

7. Conclusions and Future Work

With the current version of the PSI Ontologies we were able to formalize a real life project and we could even reuse the initial knowledge base with only minimal additions. This shows that the modeling of activities by their inputs and outputs with a few

additional constraints is feasible and that it is suitable for the application domain of semiconductor design.

To be able to improve the modeling of dependencies between activities, we still need to collect a comprehensive set of test cases. With this done, we will concentrate on new concepts and properties to create detailed models of the complexity and the quality requirements of design artifacts, the difficulty of activities, the abilities of designers and the capabilities of software tools used. In parallel, ongoing work is focusing on improving the simulation and the evaluation of the results using a growing testbed and assessing real design systems.

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e-Collaboration Platform for Metal Forming Enterprises based on the Semantic Web Technologies

Łukasz RAUCH [a, 1], Maciej PIETRZYK [a]
[a] *AGH – University of Science and Technology, Kraków, Poland*

Abstract. Structured communication between trading partners is crucial in everyday business life. A lot of solutions of this problem exist, allowing application to application (A2A), human to application (H2A) and human to human (H2H) communication. Such formalized exchange of information is, in most cases, based on the XML language structures, standardized by different organizations e.g. OASIS, RosettaNet. However, the content of these structures should also be recognized properly, thus it has to originate from specific ontology. Unfortunately, the lack of ontologies dedicated for various business activities often impede creation of efficient trading communication. Idea of the e-Collaboration platform, which combines various innovative technologies, allowing business processes description and ontology-based exchange of information, is presented in this paper. The proposed solution is dedicated for companies trading in Metal Forming branch. The example of such trading activities, based on material tests and determination of material rheological properties, is described in the following sections as well.

Keywords. Semantic Enterprise, Metal Forming, Material Test, RDF.

Introduction

The rapid development of new products created by using metal forming processes had (in recent years) great impact on metal industry and economy in many countries. Almost in every country the growth of quantity of newly designed products is observable. Unfortunately, in most cases the production processes of final goods are very complicated and expensive, what can affect the financial trim and competitiveness of industrial companies. It is caused mainly by the diversification of knowledge – part of the information needed in this process are possessed by the industry, but the other part is controlled and developed by academic units. Thus, the process requires tight and well organized cooperation between partners, representing different industry and academic branches, allowing exchange of services and knowledge in the field of the following activities:

- material tests – the plastometric tests e.g. tensile, compression or extrusion are performed to obtain models of material behaviour, so called rheological models of new materials. Many academic units possess proper equipment and

[1] Corresponding author: AGH – University of Science and Technology, Kraków, Poland, E-mail: pietrzyk@metal.agh.edu.pl

sufficient knowledge to realize this type of researches. The final model must be able to describe the material behaviour during its deformation process and is further used as the input in the Finite Element Method (FEM) simulations.

- numerical simulations of new shapes of elements using previously obtained material model. FEM simulations allow to analyze in reliable way the virtual model of new product created by using metal forming processes. Moreover, many academic laboratories are equipped with small scaled machines for performing real plastometric tests using wax models. Both of these results, namely FEM and physical simulation results, can be compared for validation purposes.

Due to the mentioned above 'academic' services, the industrial companies receive the opportunity to reduce the costs related to inefficient 'trial and error' procedures. In fact, it is not economically justified to perform real tests using industrial equipment, because of the high costs of the samples and experiments. Moreover, only large companies allow themselves to create their own research departments, which could be responsible for preparation of new products design and performance of material tests. Therefore, the precise way of communication between enterprises and academic partners should be provided. It can be supported by the implementation of e-Collaboration platform based on the structured business language [1]. It should allow creation of formalized definitions of users' needs, expectations and offers, simultaneously enhancing the collaboration between industrial and academic partners in the field of material tests and numerical simulations performance.

1. Target Group Analysis

The Target Group consists of two subgroups containing enterprises from metal industry and academic partners specialized in metallurgy or material science. The growth or recession in the sectors of chosen stakeholders is determined mainly by the successful exchange of information and services between them. Thus, it is very important to sustain the good shape of economy also by enhancement of trading processes between companies and universities or institutes. The main problem before and during the cooperation of these entities was recognized as inaccurate way of communication between customers and suppliers in services market. Unfortunately, this problem can have much more serious consequences appearing in lower quality of products or companies' financial problems. Thus, the mentioned above Internet platform solution should offer functionality, which will cover the following needs:

- enterprise A (independently of its size) would like to create new products – after phase of detailed design of products' elements the proper material and plan of its forming process should be established. These two issues can be solved only by performance of material tests, FEM simulations and inverse analysis provided, in most cases, by external academic partner. Therefore, the company A needs to describe its expectations using some formalized language, which would be understood for potential suppliers.
- organization B (university or institute) would like to create description of its profile containing its offer of material tests performance with its methodology, parameters and used materials.

- enterprise C (small company) is a supplier of material samples, which are used as input for material test. Thus, the company would like to create an offer describing such samples with their properties and prices.
- enterprise D is a specialist in FEM simulation of metal forming processes and wants to describe its activities in form of business offer.
- organization E (medium company, laboratory or institute) is a company specialized in researches on material properties and process simulation, it performs material tests, produces the samples used in these tests and simulates metal forming processes. The company needs to prepare offer of its wide range of services.

The offers of companies B, C and D have to be combined, because they are complementary for enterprise A, which is a customer in this situation. In contrary, the offer proposed by company E is self-contained and it can be analyzed independently. Then, the expectations of enterprise A and created offers obtained from other companies have to be compared. Therefore, each offer should be formulated in the same language, which would be understood for every participant of the market. Moreover, they should be formalized enough to be gathered in structured database and automatically analyzed by the dedicated software engine.

Accordingly to the determined above requirements, the XML language have to be proposed as the basic technology for the purposes of e-Collaboration platform [2]. Several most important solutions in the field of material science and metal forming, which were implemented using XML and other various web technologies, are presented in the next section.

2. State-of -the-art

The standards of various XML technologies are developed by W3 Consortium (www.w3.org) and they are widely implemented in many industrial and academic applications. One of the greatest advantage of XML usage is the possibility of demarcation of the content and presentation layers. Due to this feature XML is very flexible and powerful tool [3]. One of the most interesting applications of XML is data structuring in the fundamental layers of the Semantic Web architecture (also proposed by W3C). It is mainly used as the basis of software solutions equipped with newly created ontologies, but it can be applicable always in case of data structuring needs e.g. in database applications, Internet services or e-Collaboration solutions. There exists a lot of such systems [4], but no one offers the functionality, which could satisfy all mentioned above users' needs (see section 1.1). The examples of the representative and most popular solutions in the branch of metal industry are as follows:

- http://web.steel24-7.com/ – the most experienced web service offering the virtual market for steel trading with professional and multi-lingual support for its customers. However, the system is limited only for steel products and doesn't offer the possibility of services trading.
- http://www.metalworld.com – large world wide information trading site, which was established to promote trade in the Metal Industry. Each company can add information about its activities products and services. However, the main disadvantage of this web service is lack of formal language, which

would allow input of precise information. All data is being added in form of natural utterance in English language. In effect, the possibilities of automated browsing of companies' profiles gathered in the database is very impeded.

- http://www.commerce-database.com/metal-forming.htm – Metal Forming Industry is only a part of large vortal dedicated for gathering information about different branches and companies. The vortal contains only static information about mentioned data without possibility of dynamic advanced search.

All mentioned above solutions are very important in everyday business life of metal industry companies or academic units. However, their functionality is focused mainly on dealing products and does not cover the field of services trading or expectations description. On the other hand, additional group of solutions, which is dedicated for on-line design of integrated products or metal forming processes, is also developed. This group of applications does not allow any business activities, because it is focused only on process and products description. However, likewise the previously discussed solutions, these are also constructed using XML based platform [5], [6]. Therefore, the currently available solutions, which offer business processes management, cover metal forming field of interest or allow precise material description, should be combined into one common application. The platform proposed in this paper act as a bridge between the mentioned technologies.

3. Material Tests e-Collaboration Platform

This section contains the description of mentioned previously e-Collaboration platform in the field of material test performance. The presented solution uses several tools standardized by the international organizations, described in section 3.1 as well as the newly created ontology based on OWL and RDF description of services related to material test (section 3.2).

3.1. Useful Tools

Innovative efficient idea of design and implementation of sophisticated web application is based mainly on the utilization of reusable components, which ought to be open source, standardized and widely used in various applications. Such an architecture of the created software guarantees the possibility of easy maintenance and flexible development. In case of proposed e-Collaboration platform the following technologies should be taken into consideration:

- ebXML (http://www.ebxml.org) – Electronic Business XML is an initiative, which was established by two international organizations, namely UN/CEFACT and OASIS. The scope of ebXML covers almost every business activities of companies, independently of their size, allowing the enhancement of collaboration between them. It is focused mainly on the exchange of structured business information between trading parties in A2A, A2H and H2H manner. Two most important parts of this initiative have to be mentioned: ebCPP (Collaboration-Protocol Profile) and ebCPA (Collaboration-Protocol Agreement). Due to these solutions, precise

description of many real-life activities can be prepared e.g. business processes definition, execution, management and evolution or partner discovery and sign-up,

- RosettaNet Community (http://www.rosettanet.org) – allows clear presentation of company's business processes divided into small elements called Partner Interface Processes (PIPs). Their standards are open source and accessible in form of DTD documents and widely used by more than 1600 companies in the world. The most important PIP from the Metal Forming platform point of view is PIP 2A13 and PIP 2A15 (currently under construction).
- MatML Language (http://www.matml.org) – this web site contains the proposition of XML-based language dedicated for unified material properties description, which could be further used in simulation software, material databases or wide exchange of standardized information [7].

The enumerated above technologies are sufficient for companies, which are interested in trading materials. However, it can be clearly seen that because of the lack of the proper ontology, the description of Metal Forming Services are impeded and the communication between trading parties can be inefficient and not reliable.

3.2. Material Test Ontology (MatTest)

MatTest ontology is the answer for stated previously expectations and requirements of industrial and academic organizations. This section contains only the part of proposed MatTest ontology, because of its huge size.

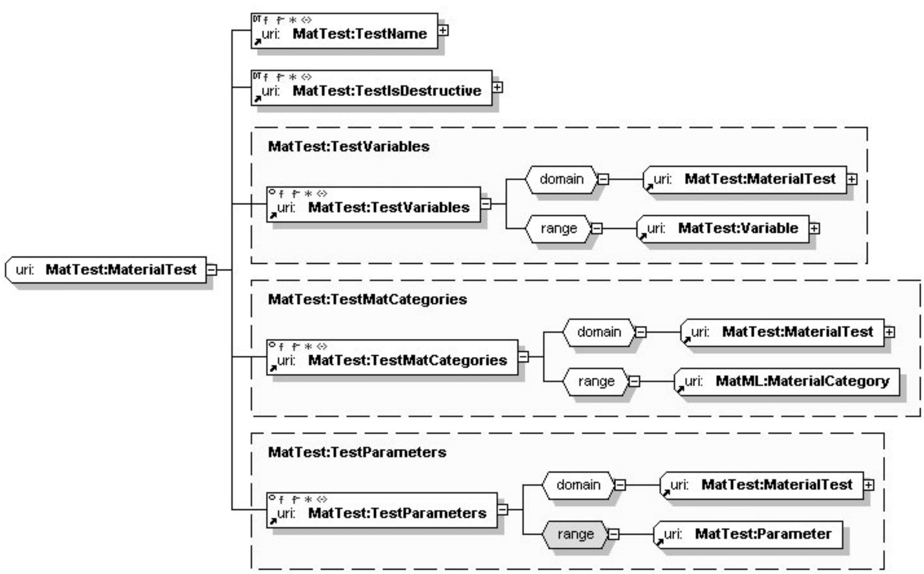

Figure 1. Simplified OWL diagram of main class *MaterialTest*.

The technologies used to create this ontology: RDF and RDF Schema– http://www.w3.org/RDF/, OWL Full – http://www.w3.org/2004/OWL/, are also standardized and proposed by W3C. This solution allows the possibility of structured description of material tests and related issues.

Figure 1 presents the main class of the proposed ontology, encapsulating several main attributes, which describe material tests e.g. tests category, variables or parameters. Moreover, additional class *MaterialCategory* is used to describe for which category of materials the test can be performed. This class originates from external ontology related to MatML language. Due to such solution, the connection between tests' and materials' description, based on the distributed architecture is being created. Additional connection to ebCPP, ebCPA and Rosetta PIPs allows to build the fundamentals of e-Collaboration platform, which is presented in the next section.

3.3. Platform Implementation

The main functionality of proposed platform is presented on sequence diagram (Figure 2).

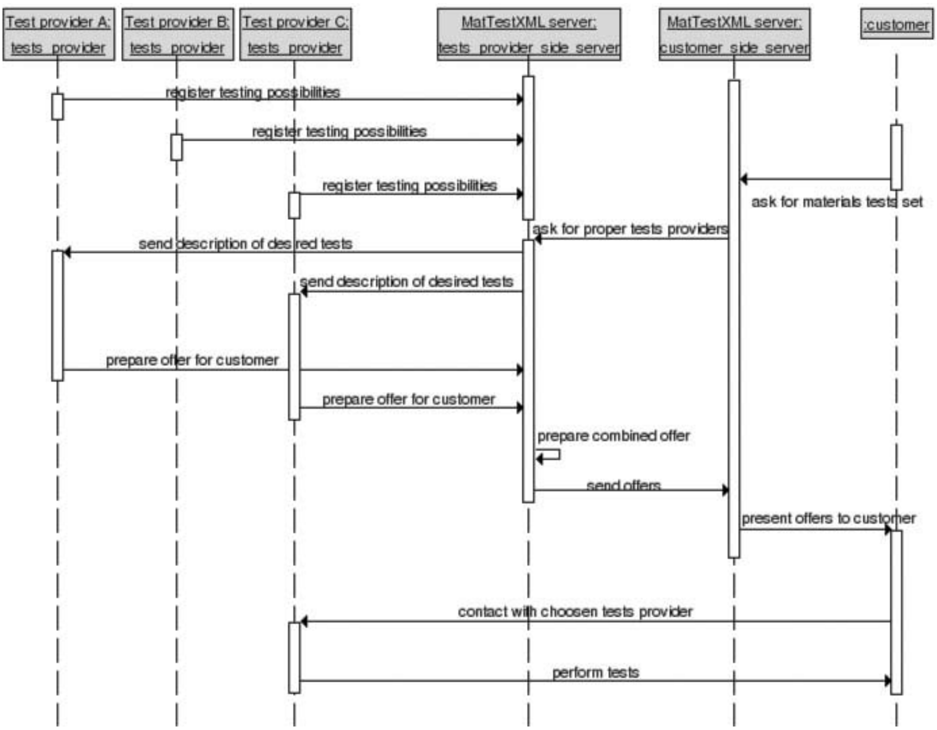

Figure 2. Main sequence diagram of e-Collaboration platform.

Material Test Providers (Suppliers) upload their offers to central server. Registered data is based on material tests specifications and company's business profile. In the next

step, customers send request to central server, describing their needs and expectations. At this moment central server is responsible for comparison of customers requests to gathered suppliers offers. Applied simple algorithms is able to find full set of offers consisting of positions, which completely or partially cover requested customer's needs. Customers queries can contain more than one material test, thus it is possible that single suppliers offer satisfies only a part of whole request. In this case, consortium of providers is automatically generated and propositions of combined offers are prepared. Such created offers are sent in broadcast manner to the interested parties and the process of partners collaborations is being started.

The implementation of platform's main functionality is based on the web services, treated as the information exchange layer based on XML language, incorporating inherent technologies. Web services can be defined as applications, which interact with other applications for the purpose of standardized XML data exchange by using specific messaging system. Thus, the top-level design of platform packages can be prepared using the assumptions concerning the web services utilization and analysis of functional requirements, including presented sequence diagram. Four main nodes of the platform have to be distinguished (Figure 3).

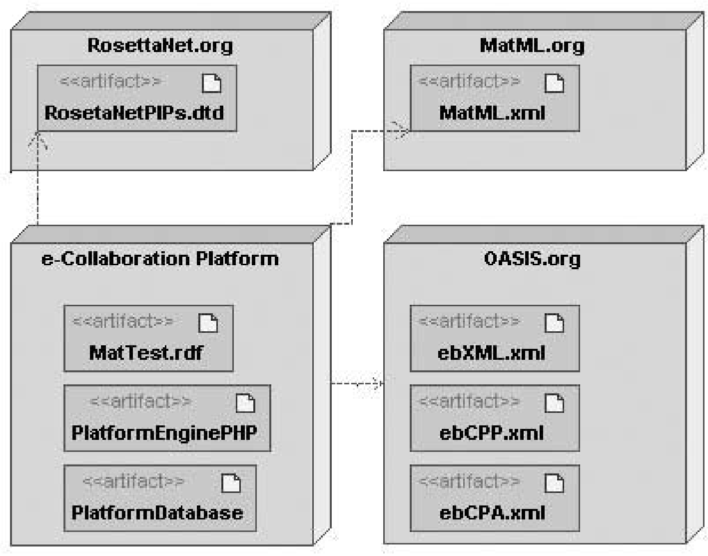

Figure 3. Deployment Diagram of main modules of e-Collaboration Platform

Main node named 'e-Collaboration Platform' is being constructed of three internal modules i.e. PlatformEnginePHP, PlatformDatabase – software interface responsible for interaction with application users and data management, and MatTest.rdf – containing the material test ontology described in section 3.2. Additionally, three more components have to be accessible, namely OASIS.org, MatML.org and RosettaNet.org. The proposed architecture is offering the sufficient functionality to start and maintain the collaboration between metal forming enterprises.

4. Concluding Remarks

The idea of the e-Collaboration platform dedicated for Metal Forming industry branch was presented in the paper. The basics of this approach are focused on the support of trading process between industrial and academic partners, interested in performance of material tests. Nowadays, difficulties with finding proper material tests provider is a big obstacle, especially for small and medium enterprises, which cannot afford to create their own research departments. Using central server, which gathers material tests offers, each interested company is able to find the partners in very short time. On the other hand, materials tests' providers obtain the opportunity to collaborate with industrial entities and enhance their knowledge and experience about new technologies.

The proposed MatTest solution fills the gap between the different XML-based technologies, which support structured description of business activities and materials properties. However, the created material tests ontology based on RDF framework has to be still developed, because of the huge diversification of test categories, their parameters and variables.

Acknowledgements

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Combining Ontology Engineering with HTN Planning

Jingge Song, Jianzhong Cha[1] and Yiping Lu
Beijing Jiaotong University, Beijing, China

Abstract. HTN planning is an efficient AI planning approach for real-world application. An ontology-based architecture for HTN planning is proposed which combine knowledge engineering with problem solving strategy. A prototype system is implemented by exporting this ontology-based KB to SHOP2 planner.

Keywords. Ontology, HTN planning, Problem solving knowledge, Prototype system, SHOP2

Introduction

The Hierarchical Task Network (HTN) is an effective mechanism for AI planning in well-structured task domain. There have been many applications of HTN planning in different areas such as construction industry, web services composing, military logistics and oil spill. However, HTN mechanism is domain-dependent, domain knowledge and/or experiences are needed to construct the task decomposition strategies. Knowledge modeling and management began to play more and more important role in HTN planning.

Ontology engineering is methodology for knowledge sharing, reuse and management. Many features of ontology can make domain modeling easily and efficiently. Now ontology approach has been used in many research areas. In AI planning area, ontology has also attracted some researchers, but in most cases, ontology modeling approach is used to model static knowledge such as domain models. Problem solving knowledge seems to receive less attention in ontology research area.

In recent years, real-world problem research became active area in AI planning community. In the International Conference on Automated Planning & Scheduling (ICAPS), some benchmarks from real-world domain have been established to promote the development of domain modeling method and algorithm.

The purpose of this paper is twofold. Firstly, the mechanism of ontology-based knowledge modeling for HTN planning is investigated in order to make problem solving knowledge construction more efficient and flexible. Secondly, we explored the implementation of a prototype system that combine ontology engineering with HTN planning.

[1] Corresponding Author: Jianzhong Cha, Beijing Jiaotong University, Beijing, China, E-mail: jzcha@center.njtu.edu.cn

1. RELATED WORKS

Fensel[1] proposed Uniform Problem-solving Method development Language(UPML) as a general purpose architecture for ontology-based knowledge modeling. This work is based on commonKADS knowledge architecture. But it is too much general and no particular application problem is concerned.

Austin Tate[2] proposed ontology for planning knowledge modeling based on <I-N-OVA> constraints specification. However, this ontology is a constraints-based architecture and no strategy is discussed. T.L. McCluskey[3] use an ontology modeling language in Rocket and Dockworker domain to show integration of ontology and AI planning. Their approach focus on static model-based planning and problem solving strategies is implemented by other knowledge system.

Our research goal is trying to make ontology engineering more widely used in knowledge-based problem solving. So our work focuses on integration and collaboration between different types of ontology and ontology-based interface with problem solving engine.

2. Ontology for HTN Planning

2.1. Ontology architecture

In Schreiber's[4] KADS architecture, knowledge system is identified as three layers— domain layer, inference layer and task layer. We adopt this idea to establish a general ontology architecture for problem solving, Three modules have been established as the following description:

- Application-Domain — represent concepts, relations and properties that associate with application domain such as device, line and system.
- PSM-Strategy — general description of problem solving strategies, including operators, task decomposition method and axioms.
- Problem — is abstract representation of domain relevant problem need to be solved such as planning, diagnosis and control.

Here we use term 'strategy' instead of KADS's term 'inference' to indicate general problem solving knowledge and 'problem' to 'task' to avoid confusing with HTN task concept. Then we can refine this architecture for HTN planning. A HTN planning ontology can be derived as a triple $Onto_{HTN} = \langle D, S, P \rangle$, where D is domain model ontology relevant to planning, S is HTN Strategy ontology, P is HTN planning problem ontology.

2.2. Domain ontology

In order to combine different domain ontologies with HTN planning, easily and efficiently, two interface ontologies are introduced by derived domain ontology into two different part or levels, Domain-Element and Domain-Model.

- Domain-Element — contains practical elements to describe an industrial system such as Device, Relation, State and Parameter.

- Domain-Model — contains Topological-Structure and State-Description ontology. Topological-Structure integrates concepts and relations to form a system topology while State-Description can describe different states of system components.

Domain-element is the basis of Domain-model ontology. By using these two ontologies, we can integrate other domain ontology modules with HTN planning ontology. Then knowledge base of domain ontology can be used for AI planning purpose.

2.3. HTN strategy ontology

In most applications, ontology is known to represent static knowledge such as object, relation and properties. Problem solving knowledge does not receive much discussion in ontology application research. However, PSM knowledge is important to knowledge-based application such as planning, diagnosis and control. HTN strategies can be seen as a type of PSM knowledge to conduct search procedure and reduce search space. According to Erol's [5] and Nau's formalism [6], HTN planning ontology is:

- HTN Strategy: $S_{HTN} = <Op, T, DS, Am>$, where *Op* is operator, *T* is task, *DS* is decomposition strategy and *Am* is axiom.
- Operator: $Op=(N, Prm, Pre, Post, Dur)$, where *N* is the name of operator, *Prm* is parameter associated with *N*, *Pre* and *Post* are pre-condition and post-condition of operator. *Dur* is duration time of operator.
- Task: $T= (N, Prm)$, where *N* is the name of task and *Prm* is parameter list binding with the task.
- Atom Strategy: $AS=(Pre, ST)$, where *Pre* is pre-conditions, *ST* is sequence of sub-tasks. Atom Strategy is basic unit of Decomposition Strategy.
- Branch Strategy: $BS = \{as_1, as_2, \ldots as_n\}$, where $as_i \in AS$ is an Atom Strategy, Branch Strategy is composted of finite number of Atom Strategies.
- Decomposition Strategy: $DS=(N, Prm, MT, BS)$, where *MT* is a main task, *BS* is Branch-Strategy.
- Axiom: $Am=(N, Desp)$, *Desp* is a description that can be filled by an individual language.

It is just an architecture for general HTN planning mechanism, no implementation language is concerned. During construction of knowledge base, a specific HTN planning language can be chosen to fill description text-area to create an instance.

2.4. Planning problem ontology

Planning-problem ontology is sub-ontology of Problem ontology. Different type of problem may have different ontology. To HTN planning problem, $P_{HTN}=<I, Op, DS, GT>$, where *DS* is set of decomposition strategy, called 'method', and *GT* is set of goal tasks, the problem is specified by a group of abstracted goal tasks. We describe planning problem in a compound formalism by building two problem elements:

- Planning-domain: ontology contains Domain-element instances to construct a complete planning domain description.
- Planning-problem: ontology contains HTN-task instances that describe planning goal tasks , which is a task sequence specifying a planning problem to be solved.

3. Prototype Implementation

In recent years, ontology and AI planning are both active areas in AI research communities. Some ontology modeling tools and knowledge-based planners have been developed to support further research. In this paper, we choose Protégé environment and SHOP2 as modeling tool and planner to implement the integration of ontology model and planning task.

3.1. Protégé Environment

Protégé[7] is an ontology and knowledge base modeling environment based on OKBC ontology modeling mechanism. As a platform-independent integrated modeling system, Protégé has become one of the most popular knowledge engineering tools in many research areas. In our Protégé implementation, besides ontologies we mentioned above, a tool-ontology is added to make knowledge acquisition and management more convenient.

This tool ontology contains two sub ontologies, one is task-list ontology aims to list planning tasks in an integrated list, the other is a portal ontology of KA tool, which is a knowledge acquisition plug-in for Protégé.

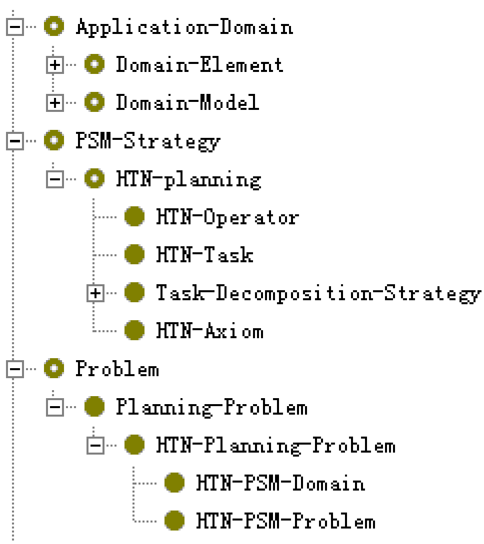

Figure 1. Hierarchy of HTN planning ontology in Protégé

3.2. SHOP2 planner

SHOP2 planner is a general HTN planner. 'Method' is defined as a simplified task decomposition strategy. Additionally, 'Axiom' is defined as reasoning rules to simplify domain model and system state. Some features are:

- Simple propositional description language based on PDDL, a description language for AI planning.

- High performance HTN search algorithm. SHOP2 adopt algorithm that plan generation sequence is the same as operator executing sequence, so complexity can be reduced during problem solving.
- Combining propositional and numerical expression. So planning reasoning can based on discrete state and continuous state description.
- Support temporal planning domain.

SHOP2 is a promising choice for research because it is an open source planner. So further work could be done by improve knowledge base representation and planning algorithm.

3.3. PlanningTab plug-in

We developed a Protégé plug-in named PlanningTab for bridging Protégé KB and different AI planners such as SHOP2. Currently, PlanningTab has the following functions:

- Translate Protégé KB instance to SHOP2 domain and problem description.
- Show SHOP2 domain and problem file for examining SHOP2 syntax.
- Execute planner by simply push 'execute' button and result can be shown in text area.

This prototype system can leverage Protégé's powerful knowledge editing and management functions.

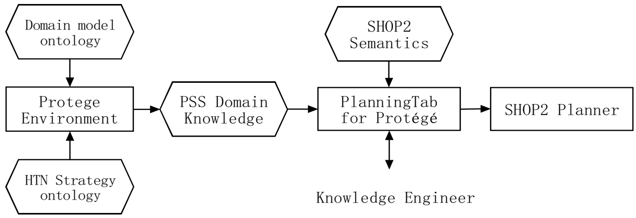

Figure 2. Architecture of prototype system

4. Use Case

4.1. Domain

Operating order is an important assistant for Power System Scheduling (PSS) in China. Operation order synthesis (OOS) is an application of AI technology. The task of OOS is to synthesis operation order in automated or semi-automated techniques according to current power system operating state and the demand of power energy in different areas.

Our task is to use ontology approach to build KB for HTN planning in this domain.

4.2. Knowledge Model

We have established an ontology architecture named *PowerOnto*[10] as a general basis for power enterprise domain model. Resource-layer and Production-layer are selected as a starting point for this work. In these two sub-ontologies, some major concepts and

relations are defined such as power-device, system, material, state, relation, parameter, etc.

In Protégé environment, we instantiated HTN planning ontology to construct several OOS oriented knowledge base. Knowledge base is organized as three parts—domain, strategy and goal task.

1) Domain knowledge components

Power system is a large-scale and complex system. Large number of devices, large-scale topological structure and multiple device states and system states are domain characteristic. So knowledge derived from domain ontology consists three parts:

- Device knowledge
- Topological knowledge
- State knowledge

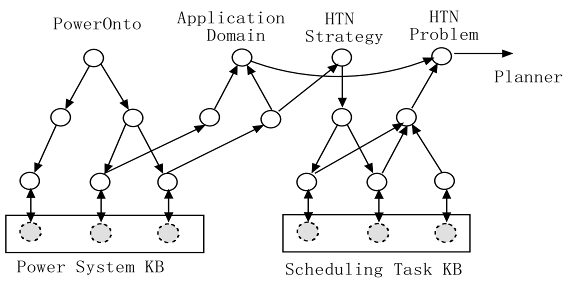

Figure 3. Knowledge flow of planning in OOS domain

We extract some of *PowerOnto*-based KB to HTN planning as show in Figure 3. Arrows from down to up or left to right show knowledge flow to HTN planning in OOS domain.

2) Task knowledge components

In PSS domain, system state is generally identified as four classes —serve state, hot reserve state, cold reserve state and repair state. So the main task of power system operation or scheduling is trying to switch between different states. For example, the following are some of the operation tasks.

Serve-to-repair(?o)

Hot-reserve-to-Serve(?o)

We simply instantiated the HTN task ontology to list these tasks. Although different power systems have different devices and structure, the top-level scheduling tasks are almost the same, so these parts of tasks usually have little change in knowledge base.

3) Strategy knowledge components

In most cases, strategy is not a branch structure from one task instance to some sub-task instances, but a template from a state pattern to a task sequence. So instance of strategy is not composed by domain instances. On the other hand, different HTN language may have different formal expression. We used SHOP2-like syntax fill the atom-method to combine KB with SHOP2 planner.

The following code is part of OOS KB in OWL format. For clarity, the namespace information has been removed.

```
% Ontology for HTN Planning in OOS domain
  Ontology(
  Class(Atom-Strategy)
    subClassOf  Class(Task-Decomposition-Strategy)
```

```
  Class(Task-Decomposition-Strategy)
    subClassOf  Class(HTN-planning)
  Class(PSM-Strategy)
  Class(Domain-Parameter)
    subClassOf Class(Domain-Element)
  Class(HTN-Operator)
    subClassOf Class(HTN-planning)
  Class(PSS-Transformer)
    subClassOf Class(Domain-Device)
  Class(Domain-Model)
    subClassOf Class(Application-Domain)
  Class(HTN-Axiom)
    subClassOf Class(HTN-planning)
  Class(Domain-State)
    subClassOf Class(Domain-Element)
  Class(PSS-Fuse)
    subClassOf Class(Domain-Device)
  Class(ext)
    subClassOf Class(Topo-Relation)
  Class(Domain-Element)
    subClassOf Class(Application-Domain)
  Class(Sub-Branch-Strategy)
    subClassOf(Branch-Strategy)
  ...

  ObjectProperty(sub-tasks domain(Atom-Strategy))
  ObjectProperty(planning-domain domain(Planning-Problem))
  ObjectProperty(proposition-facts domain(Device-Parameter))
  ObjectProperty(topo-table domain(Topology-description))
  ObjectProperty(methods domain(PSM-Domain))
  ObjectProperty(devices domain(KATool))

  DatatypeProperty(precondition domain(Atom-Strategy Operator))
  DatatypeProperty(postcondition domain(HTN-Operator))
  ...
)
% Knowledge base for OOS domain
  PSS-Breaker(bk04)
  HTN-Operator(!close ?s)
    precondition(((switch ?s)(opened ?s )))
    postcondition(((opened ?s))((closed ?s)))
    language(SHOP2)
  HTN-Operator(!open ?s)
   postcondition(((closed ?s ))((opened ?s )))
    precondition(((switch ?s)(closed ?s )))
  HTN-Axiom(unchecked-axiom)
    description((unchecked ?s)((not(checked ?s))))
    HTN-Axiom(different-axiom)
   description((different ?x ?y)((not(same ?x ?y)))
  PSS-Line(l1)
  PSS-Line(l2)
   ...
```

4.3. Some Features

Prototype system experiments show that there are some features for this architecture:

- Modifying and extending knowledge become easy and flexible.
- Strategies modeling can reduce inconsistency.
- To some different instances of power system, only some middle level task decomposition methods should be extend and revised.
- It is a rich knowledge platform that can be used to improve functions of planners.

5. Conclusion

Adapting knowledge engineering approach, especially ontology approach will provide a large space for collaboration between knowledge and planners. Our ontology is clear and easy to understand. Combining Protégé and SHOP2 is a promising approach for investigating knowledge-based AI Planning system.

Currently, we do not discuss constraints as knowledge to help planning task. We also do not concern process knowledge in application domain. Now the system can only export Protégé knowledge to SHOP2 format, we plan to support more planners' format and import different kind of planner's KB to Protégé format in the future. So multi-planner collaboration can be implemented.

Acknowledgements

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The Semantic Web for Improving Dynamic Tourist Packages Commercialisation

Idoia MURUA[a] , Esteve LLADÓ [b] and Bel LLODRÁ [c]
[a] *ROBOTIKER, Parque Tecnológico, Edif. 20, E-48170 Zamudio Bizkaia (SPAIN), idoia@robotiker.es*
[b] *Fundación IBIT, Parc Bit. Ctra. Valldemossa, Km. 7,4, Edif. 17 - Planta 3ª Porta D-2, E-07121 Palma de Mallorca, Mallorca (SPAIN), ellado@ibit.org*
[c] *Fundación IBIT, Parc Bit. Ctra. Valldemossa, Km. 7,4, Edif. 17 - Planta 3ª Porta D-2, E-07121 Palma de Mallorca, Mallorca (SPAIN), bllodra@ibit.org*

Abstract. The use of Semantic Web technologies allows us to annotate information sources on tourism services and products with the concepts included in a defined ontology. The enriched information can be used to match tailored package holidays to client preferences and according to real time availability. This paper presents the ANOTA project approach to aggregation of tourism information according to user and destination management strategy. The main hypothesis is that an official promotional tourist information portal can integrate tourism information from different sources and present it in an aggregated way, according to current user search and marketing strategy.

Keywords. Semantic Web, annotation, tourism ontology, dynamic packaging, information integration, syndication, metadata.

Introduction

Nowadays, when a user wants to plan a holiday trip using the Internet, he needs to visit different Web pages, each of which offer a different tourism service, e.g.: the transport, the accommodation and the activities he can perform in the place. This is a consequence of the fact that in the tourism market there is a predominance of SMEs from different subsectors. Value-chain integration consists of the combination of various tourism services.

The use of Semantic Web technologies can facilitate the integration of tourism information not only about sources or providers but also about available services.

In the ANOTA project, co-funded by the European Union, Spanish Ministry of Science and Education, a pilot implementation is done at the Balearic Islands. One of the objectives of the ANOTA project is to demonstrate how tourism information annotation will work applied to dynamic packaging of tourism services in a real-world scenario. This will allow users to organise easily their own tourist package.

Information on tourism sources and services on offers to consumer are described using concepts of a specific ontology, defined according to destination characteristics and its resources. The official destination portal presents aggregated information.

The user searches information according to their preferences. The novelty of the pilot is that the results of a search are shown aggregated, covering all services -

accommodation, transport and activities- needed to arrange a trip. The result only shows resources available for the dates and resort chosen. This is possible due to the association of services with the semantic concepts defined in the ontology. The search is carried out simultaneously on different information sources and results are shown in the portal as an integrated view.

1. Scenario Description and User Interface

The ANOTA project, via a Semantic Web pilot, aims to combine information from different portals. The added value is that the users will be able to assemble their own holiday components and create their own tailored package.

The user will not need to visit every web-site that provides information on a selected destination, but from a unique portal will have access to all information on tourism services from the Web.

The destination chosen to implement the ANOTA project pilot on the Semantic Web is the Balearic Islands.

Three types of portals provide the information, which will be semantically annotated:

- Those providing mainly cultural and destination information
- Portals providing accommodation information and services
- Portals providing flight information and transport services

Figure 1 shows the mainframe of the search portal that will be used by the user.

Results of the search will be shown in an aggregated way. If a user is interested on a certain event, for example “Copa del Rey de Vela”, the application will suggest flights available for the competition dates and accommodation vacancies situated close to the competition location.

A future improvement to the actual project will be to allow the providers to add their offers as RSS feeds, semantically enriched, in order to include them into the search portal. Then, when a user performs a search including their preferences – places to visit, dates, etc. – the results will not only cover the relevant searched information, but also information about complementary offers that could be interesting for the user.

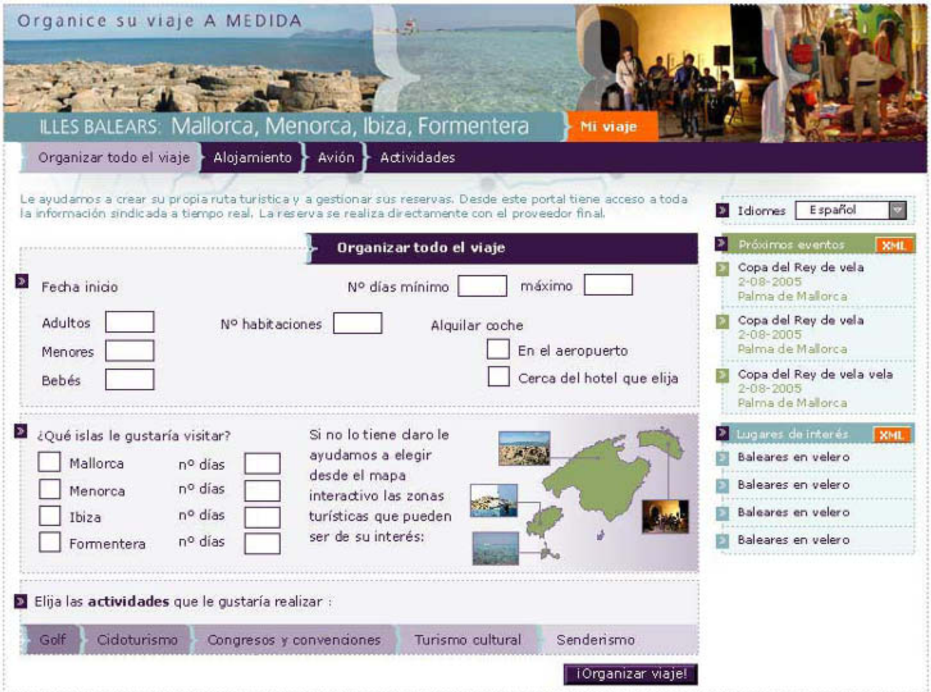

Figure 1. Users interface of destination portal

2. Architecture and Process

Tourism enterprises will provide information which will be semantically enriched with an annotation tool, based on the terms of a common ontology.

To be able to extract the information in a common RDF format from every provider, and a format based on the schema of terms defined in the ontology used, it is necessary to develop a wrapper for every dynamic source. These wrappers will be in charge of transforming the data from the original data format of the providers, into RDF metadata and according to the schema of terms defined in the ontology. The optimal update frequency of these RDF metadata will depend on the update frequency of the original data.

Tourism enterprises will provide information, in two formats, depending on the type of information:

- RDF [1] sources, which will contain information on geographical areas, provider's information on vacancies and availability (accommodations, …).
- Feeds RSS 1.0 [2], which will contain information with an advertising component, as flight and accommodation offers. This option, although not implemented yet, is presented here as a future improvement to the service.

A service provider will be able to register its source in the directory by means of filling in a form. An administrator will validate the enterprise information and enrich semantically the source description according to the concepts of the ontology. He will use an annotation tool developed in ANOTA project for doing so.

The architecture is based on Sesame RDF Repository [3][4]. Sesame is used as a directory to register and discover sources and feeds, and to store metadata for the aggregation portal. The SeRQL query language [5] is used to perform the queries.

The aggregation portal will search sources and feeds in the directory, according to the criteria expressed by the user. Figure 2 shows a general view of this process.

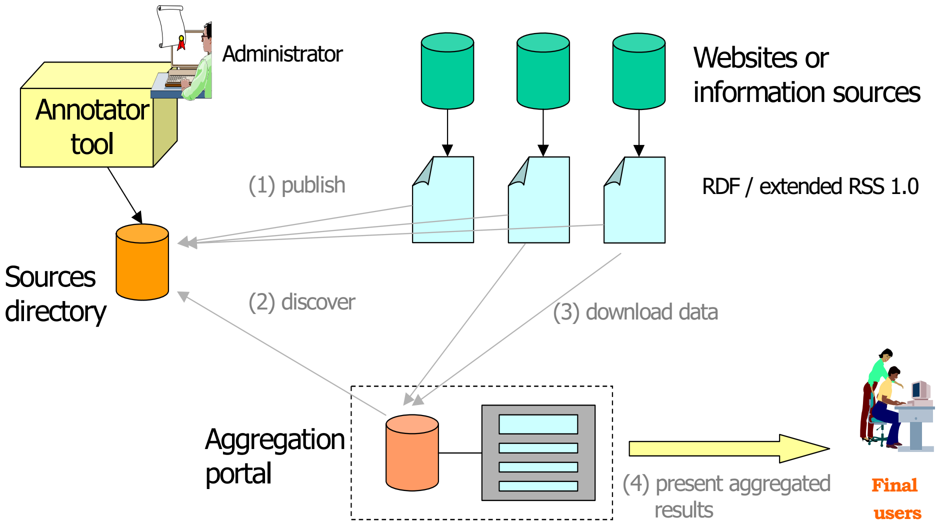

Figure 2. General view of the process

Users will be able to carry out the searches with a single interface (aggregation portal). The application will discover relevant sources and collect data from the sources according to search parameters and their semantic relationship, avoiding a download of available information from all sources.

3. Definition and Use of the Ontology

The ontology has been created reusing parts of a previous defined ontology -as the work done by the Open Travel Alliance (OTA) [6]- in order to define the concepts used in the user interface.

The ontology has been defined to annotate the content of the different sources to be integrated (flights, accommodation, activities). This ontology could also be used to extend RSS 1.0 to include more semantic structures in these type of feeds.

Tools that are currently available on the market are stable enough for ontology development. The tourism ontology used in the ANOTA project has been edited using Protégé [7].

4. Conclusion

This pilot experience will enable the advancement to the concept of Dynamic Packaging, present in the Tourism Industry, with the use of Semantic Web technologies.

The advantage of using semantic annotation regarding other types of technologies is the possibility of combining and visualising the information coming from diverse and different sources according to a common view in an aggregated way. Thus, the information is visualised and organised in the "front office" according to the data schema defined in the "intelligent search" portal and not as determined by each data structure of the original sources of the tourism information.

Apart from benefiting the final user, this will also have an important effect for SME's as their webs have more opportunities to be found and visited.

The fact that a tourism entrepreneur enriches their information with metadata and syndicates it, gives more visibility and promotes distribution on other channels. Thus, it gives an added value as it enables aggregation of the information in tailored tourist packages.

Moreover, the destination marketing portals will be more complete, as they will not only offer general tourism information, but also real on-time availability of vacancies according to searches carried out by users.

5. Acknowledgements

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Improving Mappings Discovery for Semantic Interoperability

Catarina FERREIRA DA SILVA [a, b, 1], Lionel MÉDINI [b], Celson LIMA [a], Parisa GHODOUS [b]
[a] *Centre Scientifique et Technique du Bâtiment, F-06904 Sophia-Antipolis, France*
[b] *Laboratoire d'InfoRmatique en Image et Systèmes d'information, CNRS UMR 5205, Université Claude Bernard Lyon 1, 43, boulevard du 11 novembre 1918, F-69622 Villeurbanne cedex, France*

Abstract. This paper presents an approach to enhance semantic interoperability between semantic resources for the construction sector. It extends the approach developed by the FUNSIEC project through a set of propositions intended to increase the quantity and the quality of semantic mappings. The evaluation of the semantic mappings targets two directions, i.e. to assess the quality of the mappings using fuzzy logic techniques and to calculate how much a specific mapping is appropriate to a user context. Conclusions and further work are also discussed here.

Keywords. Semantic interoperability, semantic mappings, semantic resources, ontology, mappings evaluation

Introduction

More and more actors and agents involved in concurrent engineering activities use *Semantic Resources*[2] (SR) to structure and exchange information about products and processes. A SR can for instance be used to categorise and to provide definitions for the terms that describe the features of a product. Each SR is a window showing how a company organises the information to be handled by its experts.

During a collaborative project, actors come from different organisations or companies and perform different tasks. Unless a common standard prevails and supports the majority of these tasks, whenever meaning come into play, actors use tools that rely on their inner way to model information and express semantics. We are thus talking about collaboration processes where heterogeneity is a common feature.

Due to the very nature of concurrent engineering projects, actors often perform tasks that use or modify equivalent data in several of these representations, as well as data linked by complex *semantic relations* (*i.e.* mappings). In order to ensure data consistency, each project should then be supported by back-office mechanisms that ensure interoperation between *heterogeneous* SRs. Such mechanisms would perform syntactic transformations from one format to another, as well as semantic mappings.

1 Corresponding Author: Catarina Ferreira da Silva; E-mail: catarina.ferreira.da.silva@liris.cnrs.fr

2 Semantic Resource is an expression coined in the SPICE project which refers all ontology-similar entities, such as taxonomies, dictionaries, thesauri, etc.. Two arguments supported this choice: there was no consensus by that time about what ontology really is and there was a myriad of expressions available to define ontologies and similar resources. They are both still valid.

This article aims at pointing out our current work and perspectives towards achieving interoperability between SRs in the construction sector.

In particular, we herein deal with *semantic interoperability*, which in general refers to "the ability to exchange information and use it, ensuring that the precise meaning of the information is understood by any other application that was not initially developed for this purpose" [1]. To give a more detailed definition of our view of semantic interoperability, we would say that it aims at discovering, taking into account and processing, a maximum number of *mappings* found between elements of a set of SRs, in order to improve communication among actors. This paper specifically discusses techniques to enhance semantic interoperability by improving discovery of mappings, qualification of mappings and comparison processes.

The paper is structured as follows. Section 1 presents the context, the proposed approach, the used techniques, and the work already done. Section 2 identifies the current challenges and discusses the ways of improving the mapping discovery process as well as the qualification of the mappings. Finally, section 3 draws some conclusions and points out the future work.

1. Rationale

Efforts around standards target to improve interoperability, such as the ISO/PAS 16739[3], and to represent the Building Construction (BC) information, like the ISO 12006[4]. Nevertheless semantic interoperability among SRs is not a finished quest in the construction sector particularly with the advent of the Web. International projects targeting the Construction sector are increasing and the international e-market for products and projects (Construction specific) develops. Actors keep doing construction products in the e-world where interoperability entered into a new level of research. Different projects lean frequently on unlike SRs and this induces the growing need to use several SRs (semantically heterogeneous) that have to be semantically connected.

1.1. Context

The work presented here is the result of the collaboration between two research organisations, namely CSTB and LIRIS. CSTB, the *Centre Scientifique et Technique du Bâtiment* (helps the Construction sector – at both French and European levels – in many areas, ranging from quality conformance testing process to the simulations of natural events using virtual reality facilities. CSTB also works with Knowledge Management (KM) related technologies and techniques, through the development of software tools supporting KM practices as well as the design and creation of taxonomies, ontologies, and classification systems [2, 3, 4]. Moreover, CSTB provides this work with real technical application data and material.

LIRIS is the Lyon research centre for images and information systems. It is a French academic laboratory that has been working for several years on means to improve collaborative processes, in diverse activity domains. In parallel, it has a recognised contribution in artificial intelligence and semantic web research domains. The collaboration between CSTB and LIRIS puts efforts and up-to-date abilities in

3 Industry Foundation Classes (IFC2x) Platform Specification

4 Building construction - Organization of information about construction works

information science research fields together in order to forward research on semantic interoperability in those domains.

Accordingly to the roadmap published by the Roadcon IST[5] project [5], the construction industry is heterogeneous, highly fragmented and highly regulated. The business relationships are temporary and often short-term, bringing together partners who may never work together again. The construction professionals have different viewpoints (e.g. technical and cultural) over the projects and they also have to consider specific regulations from different countries, which lead them to have different interpretations over the – shared – project-related information.

1.2. General Approach

Our approach to handle semantic heterogeneity (in Construction) can be stated as the problem of discovering, expressing and using semantic mappings among SRs. The proposed methodology, illustrated in Figure 1, is split into the following phases: selection of SRs, conversion, production of concept mappings, production of role mapping, assessment of results.

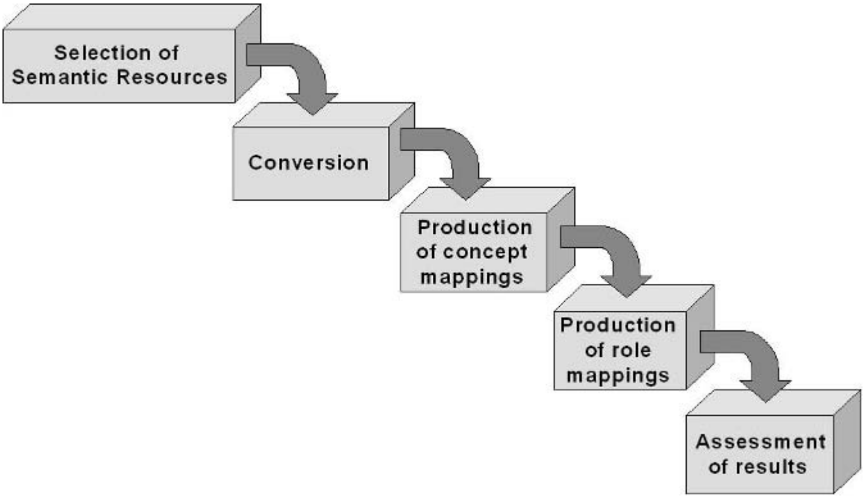

Figure 1. Phases of the methodology

In the first phase, the appropriate SRs to align are selected. This is done according to specific criteria such as the domain represented, the information richness, representation formalism, and underlying natural language. In fact SRs should represent the same domain of knowledge otherwise the mappings produced would either poor or would not exist. Information richness is related to the need of vast existence in each SR of attributes and roles that relate concepts to data types and to other concepts respectively. The second stage of the methodology deals with syntactic heterogeneity. It converts each SRs from their native formats to the Ontology Web

5 IST stands for Information Society Technologies.

Language – Description Logics subset. OWL-DL was selected as a reference (or neutral) format due to its expressiveness and the explicitness of its semantic representation, which allow automated deduction. The third stage is about the reasoning process that produces a list of mappings between concepts of the converted SRs. It is done by a DL-reasoner [6]. The phase named "production of role mappings" intends to improve the mapping process and to produce new semantic mappings. This phase relies on a taxonomy of roles and we elaborate on it in section 2.1. In this work, a role is *a semantic relation between two concepts and corresponds to a verb in natural language*. For instance, in the sentence **client buys product**, the terms **client** and **product** are concepts and **buys** – the action – is the role. The last phase of the methodology is performed by the BC experts who assess the relevance of the each discovered mapping. Some techniques to help evaluating mappings are presented in section 2.2.

1.3. Used Techniques

Following the categorisation presented in [7], several methods can be used to find mappings between SRs, namely terminological, structural, extensional (i.e. based on instances) and semantic methods. Those methods come from different disciplines such as data analysis, machine-learning, language engineering, statistics or knowledge representation and reasoning. On the one hand, their applicability depends on the type of SRs features (e.g. labels, structures, instances) to be compared. On the other hand, they depend on the expected type of results.

We focus our attention on semantic methods because they intend to discover relations between entities (concepts, relations, etc.) belonging to different schemata based on the meaning of those entities. We agree with Bouquet and *et al.* [8] when they claim that mappings should have an explicit and formal semantics, as this is the minimal condition for their usability in any semantic-based application. Moreover, formal and explicit semantics are crucial to automated deduction. Formal semantic methods help to retrieve valid correspondences according to the unambiguous semantics of SRs and input axioms[6].

Semantic methods may use reasoning techniques. Most of computer-enabled reasoning that try to yield valid arguments are based on logic formalisms. Examples of Semantic methods are the propositional *satisfiability* techniques [9] and the description logic (DL)-based techniques [10]. Standard DL techniques apply *subsumption* algorithms used by some inference engines to establish relations between concepts.

1.4. Work Already Done (Semantic Mappings Discovery)

Before the mappings discovery process, the conversion process enables to convert the native formats EXPRESS ISO 10303-11[11], XMI [12] and XSD [13] of the input SRs into OWL-DL [14]. The conversion is achieved using a converter software tool based on the JavaCC compiler[7]. This process is detailed in [6].

The goal of the mappings discovery process is to compare two SRs in order to detect the relationships between two concepts from different SRs. This process is

[6] An axiom is a sentence or proposition that is a formal logical expression and serves as a starting point for deducing other truths.

[7] JavaCC stands for Java Compiler and is available https://javacc.dev.java.net/.

performed by the FUNONDIL prototype system[8], developed during the FUNSIEC project[9]. This project investigated the feasibility of creating an Open Semantic Infrastructure for the European Construction Sector (OSIECS). FUNSIEC produced a set of mappings amongst concepts from four semantic resources (e.g. IFC, ISO 12006-3, e-COGNOS [2], bcXML [3]) currently available for the European Construction sector. The system integrates a reasoner named ONDIL [15] that is based on the FaCT inference engine [16].

The output of the mapping process is a list of different semantic mappings of the following types: *equivalence*, *subsumption*, *conjunction* and *transitivity* [6]. More than 100 mappings were produced between a set of 4 SRs of over than 20 000 concepts and relations.

2. Improvement of the semantic mapping-based interoperability approach

2.1. Augmenting the Set of Discovered Mappings

We experience the set of produced mappings can be enlarged if the number of axioms added at the beginning of the reasoning process is increased. However, this implies more efforts on the handmade analysis and comparison tasks of the SRs to map. Therefore, we believe semantic interoperability can be improved if several approaches can be combined to add axioms in the semantic mappings discovery process. In particular, we focus on terminological and extensional methods. Terminological methods apply natural language processing (NLP) techniques to find associations between instances of concepts. These kinds of methods can be useful when the concept definitions are expressed in natural language instead of logical and formal languages. Example of NLP techniques are morphological and syntactic analysis based on the internal linguistic properties of the instances or the use of external linguistic resources, such as lexicons and multilingual dictionaries [7]. Extension-based methods compare the extension of classes, i.e., their set of instances. One of the techniques that can be applied is to test the intersection of two classes (or the set of their instances) of two SRs. Other techniques try to calculate the distance between the elements of the sets [7].

Another current research track is the use of a taxonomy of roles to improve mapping results. For instance, consider two roles classified as sibling roles[10] in a taxonomy of roles. Each role is detected in one of the SRs of the application domain, and links two concepts. Both roles can be substituted by their super role of the roles taxonomy. A semantic sibling relation is then detected between those roles of the SRs and the concepts involved are related through the super role. In order to establish a roles taxonomy some taxonomies of verbs exist. For instance, VerbNet is a hierarchical lexicon of over 4 100 verbs organised into classes according to Levin's classification [17]. This lexicon classifies the general common usage of verbs. In other words, it is a generic classification. We think this valuable verbs classification is not suitable to describe the terminology of a specific domain such as the Construction sector (a generic classification has to cope with the polysemic verbs, whereas in a domain-

[8] The FUNONDIL system is available at http://195.83.41.67/ondil/connect.html.

[9] More information about the project is available at http://www.funsiec.org

[10] Sibling roles are at the same level in a hierarchical classification and are both subsumed by the same super concept.

specific classification the ambiguity can be reduced). We then need to construct a taxonomy of roles based on the existing ones and tailored to the application domain.

2.2. Evaluating the Mappings

Once the mappings have been discovered, they need to be evaluated, in order to determine how to use them for the different "mappings-based services" that will be provided by the system. We are then building a two-steps "qualification" schema for those mappings.

First, we need to determine the degree of certainty of the mappings (*e.g.* how expressive the mapping is). This step consists in answering the following question: How much each entity contributes to each mapping? For example, if we consider a subsumption mapping detected between the concepts A and B, we want to be able to say whether 80% of the description of the concept A participates in the description of the concept B, or if it is only 40%. Several research fields can help solving this problem, based on contents analysis, such as fuzzy logics [18]. This process is specific for each mapping and can be initiated as soon as a mapping is identified. This is not a real-time process (analogously to the discovery of mappings), but is performed in advance compared to the exploitation of the mapping results, then each mapping description and 'quality' value can be stored together. No other calculation is thus done at execution time than a "back-office request" to the resource storing the mappings.

Second, we need to compare the different mappings corresponding to a specific user request. This aims at ranking these mappings by order of relevance, before "packaging" the response and sending it to the client module. Different parameters can be taken into account to do this, including of course the 'quality' value determined during the previous stage, but also other contextual parameters, such as the knowledge the system has about the user and his/her current tasks, the accountancies between the environments (domains, languages, enterprises, etc.) to which belong the mapped entities, and the services that will use the mappings produced. This is a real-time process that cannot be performed in advance, since each request can correspond to different entities and provides the system with variable contextual parameters.

3. Conclusions

The work presented here extends the results achieved by the FUNSIEC project, which investigated the feasibility of creating an open semantic infrastructure for the Construction sector in Europe. FUNSIEC produced a set of mappings amongst concepts from four semantic resources currently available for the Construction sector. The paper discusses how we can improve the mapping discovery process in order to foster semantic interoperability in collaborative processes relying on semantic resources.

On the one hand, we present an approach intended to increase the set of semantic mappings. This approach relies on a taxonomy of roles to discover more semantic links between entities of the input semantic resources.

On the other hand, we discuss techniques to evaluate the produced mappings. We are working on two approaches. One approach applies fuzzy logics techniques and can be calculated in advance, i.e., before using of the mapping results. The other approach

depends on the user request and on each particular context of the demand. As so it is a run-time process.

We intend to consolidate both approaches, which means to augment the set of semantic mappings and to evaluate the produced mappings by targeting their implementation, evaluation and assessment in a real construction case study.

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A Mapping from Pi-Calculus into BPEL

Faisal Abouzaid [1]
Ecole Polytechnique of Montreal

Abstract. In the world of Web services composition languages, Business Process Execution Language for Web Services (BPEL or BPEL4WS), proposed by major vendors such as BEA, IBM or Microsoft has become the standard. However, its definition has not been formalized and this is penalizing for verification of correct behaviour of business processes. Several works have been dedicated to this purpose. Petri nets have been widely used to model Web services composition, but the π-calculus language seems to be more adequate for several reasons. For this process algebra , techniques and tools exist which make it possible to model-check any specification. To do this , one can map BPEL programs to π-calculus process and then perform verification. A more promising way is to directly build π-calculus model, to check it and then map it to a BPEL process model. This papers describes a mapping from π-calculus onto BPEL process model.

Keywords. Web services, orchestration, BPEL, formal methods, pi-calculus

1. Introduction

BPEL is the language used to express Web services (WSs) orchestrations and which seems to join together around him greater unanimity ([7], [2]). This language is supported by IBM and Microsoft and is in the way to become a standard. It is a programming language for implementing the execution logic of a business process based on interactions between the process and its partners. A BPEL process defines how multiple service interactions with partners are coordinated internally to achieve a business goal (orchestration). BPEL can specify highly complex processes is not very intuitive. Its XML representation is very verbose and there are many, rather advanced, constructs.

As an example of the complexity of automatic generation of BPEL code is the that simple things can be implemented in several ways. For example a sequence can be realized using the sequence or flow elements, a choice based on certain data values can be realized using the switch or flow elements, However, for certain constructs one is forced to use the block structured part of the language, e.g., a deferred choice can only be modeled using the pick construct [10].

We previously [1] discussed a mapping from BPEL process to π-calculus based on a semantic presented in [5] and we presented the basis of a framework dedicated to verification of Web services choreographies based on the π-calculus.

In this work, we aim to allow an automatic translation between the two languages that permit designing and verifying in π-calculus and then translating the specification

[1]Correspondence to: Faisal Abouzaid, CRAC laboratory at Ecole Polytechnique of Montreal, Quebec, Canada. Phone: (514) 340-4711 # 7386; e-mail: mohamed-faical.abouzaid@polymtl.ca.

onto BPEL. The objective is to generate compact and readable BPEL template code, i.e., we carefully try to discover patterns in the π-calculus processes that fit well with specific BPEL constructs. We hope that, by this way, we can build BPEL specifications that are easily readable and maintainable.

We base our work on π-calculus, a formal language which has been proven to be suitable to formalize Web services. In general, process algebras fit specification of composite Web services [4], because they offer a formal description of dynamic processes, which facilitates their automatic verification, with a great expressivity. They enable one to analyze the problem at hand and to sketch a solution using an abstract language that permit to deal only with essential concerns. One can use therefore existing tools to model-check the specification and verify behavior equivalences (bisimulation).

The remainder of this paper is organized as follows. First, we provide an overview of related work (Section 2) Then, we present some preliminaries including the BPEL language (Section 3.1) and π-calculus (Section 3.2). Then, in Section 4, we show a way (algorithm) to map π-calculus processes to BPEL activities using adequate annotations (Section 4.3). Finally, in Section 5, we present an example of translation, and in Section 6 we conclude the paper with some conclusions.

2. Related work

The closest work to our approach are those from Van der Aalst [9] and Ferrara [4] :
In [9] authors present a first attempt to map WF-nets (a sub-class of Petri nets) onto BPEL processes. Their objective is to use a graphical formal language to create BPEL specifications, in order to ease design and verification of composite WSs.

In [4] authors present some arguments in favor of usage of process algebra (PA) for designing and verifying BPEL specifications. Going from BPEL to a PA allows the verification step in PA, and the converse allows to see the counterexamples directly in BPEL. One can correct in PA, and the BPEL corrected code is automatically generated. This approach is useful also for reverse engineering issues, and when one wants to verify BPEL services developed by others. [9] relies on Petri nets, that have some limitations in modelizing business process (see [8]). In [4] use Lotos language for the translation. This language cannot deal with mobility issues unlike π-calculus.

3. BPEL language and formalisms

3.1. Business Process Execution Language for Web Services (BPEL)

A BPEL specification describes the execution order between a number of activities constituting the process, the partners involved in the process, the messages exchanged between these partners, and the fault and exception handling specifying the behavior in cases of errors and exceptions.

A BPEL process itself is composed of elements called activities which can be primitive or structured. Examples of such activities are: `invoke`, invoking an operation on some Web service; `receive`, waiting for a message from an external source; `reply`, replying to an external source; `wait`, waiting for some time; `assign`, copying data

from one place to another; `throw`, indicating errors in the execution; `terminate`, terminating the entire service instance; and `empty`, doing nothing. Complex structures are defined use the following activities: `sequence`, for defining an execution order; `switch`, for conditional routing; `while`, for looping; `pick`, for race conditions based on timing or external triggers; `flow`, for parallel routing; and `scope`, for grouping activities to be treated by the same fault-handler. Structured activities can be nested and combined in arbitrary by the usage of `links` (sometimes also called `control links`, or `guarded links`).

`Partner links` describe links to partners, where partners might be services invoked by the process or services that invoke the process or services that have both roles (they are invoked by the process and they invoke the process).

BPEL 2.0 : Note that the forthcoming WSBPEL 2.0 standard include new functionalities such as `For Each` that provides the ability to execute, either sequentially or in parallel, a BPEL Scope activity for n occurrences; `Break` which provides the ability to force the completion of iterations; `Continue` that terminates the execution of a single iteration; `Suspend` which stops the execution of a process instance, pending external intervention.

3.2. π-calculus

3.2.1. Introduction

The π-calculus [6], is a well known process algebra which has been widely studied during the last years. It can describe mobile concurrent computation in an abstract way and provides a way to define labelled transition systems which can exchange communication channels as messages. Name communication, together with the possibility of declaring and exporting local names (scope extrusion), gives this calculus a great expressive power.

3.2.2. The π-calculus Syntax

We refer to [6] for a detailed description of the π-calculus, but we will give here a brief introduction to its syntax. The π-calculus consists of *Action* (the set N of names for actions) and *Action prefix*. An action prefix represents either sending or receiving a message (a name), or making a silent transition (τ). Actions syntax and the set of π-calculus process expressions are given in Table 1.

Action syntax			Process syntax		
$P ::=$	$x(y)$	receive y along x	$P :=$	0	(null)
	$\overline{x}\langle y\rangle$	send y along x		$\mid \sum_{i\in I} \pi_i P_i$	(Prefixed sum)
	τ	silent action		$\mid P_1 \mid P_2$	(Parallel composition)
				$\mid (\nu a)P$	(Restriction)
				$\mid !P$	(Replication)

Table 1. π-calculus Actions and Process syntax

The meaning of each process defined above is as follows :

- 0 (*Null*) is the deadlocked process which cannot involve with any transition.

- $\sum_{i \in I} \pi_i P_i$ (*Prefixed sum*) can proceed to P_i by taking the transition of the prefix π_i.

- $P_1 \mid P_2$ (*Parallel composition*) is a process consisting of P_1 and P_2 which will operate concurrently, but may interact with each other through actions/co-actions.

- $(\nu a)P$ (*Restriction*) means that the action/co-action a or $\overline{a}$ in P can neither be observed outside, nor react with a or $\overline{a}$ outside the scope of P.

- $!P$ (*Replication*) means that the behavior of P can be arbitrarily replicated.

Structural operational semantics of the π-calculus is given by reaction and transition rules as shown in Table 2.

$TAU : \tau.P + M \longrightarrow P$	$REACT : \dfrac{}{\overline{x}.\langle y\rangle.P \mid x(z).Q \longrightarrow P \mid \{y/z\}Q}$
$PAR : \dfrac{P \longrightarrow P'}{P \vert Q \longrightarrow P' \vert Q}$	$RES : \dfrac{P \longrightarrow P'}{(\nu x)P \longrightarrow (\nu x)P'}$
$STRUCT : \dfrac{P \equiv P' \; P' \longrightarrow Q' \; Q \equiv Q'}{P \longrightarrow P'}$	

Table 2. reaction and transition rules of the π-calculus

The free channel names of π-calculus expressions in particular, play an important part in the translation. Expressions $x(y)$ in $x(y).Q$ and νx in νxQ, are binders ($fn(\nu xQ) = fn(Q) - \{x\}$ and $fn(x(y).Q) = fn(Q) - \{y\}$) . Dynamic behaviour can only take place under parallel compositions and νx binders. So, communication must be done either entirely inside, or entirely outside the scope of a νx binder. This is possible due to the congruence rule : $(\nu zQ1|Q2) \equiv \nu z'(Q1\{z'/z\}|Q2)$.

4. Mapping π-calculus into BPEL

4.1. General Outline

A WS orchestration shows WSs running in parallel and this can be represented by a main π-calculus process that is composed by parallel and synchronizing actions. So the basis of the mapping is a correspondence between π-calculus and BPEL activities. While translating π-calculus onto BPEL, designers have to care about instantiating all the processes representing services, in order to ease the translation to a readable and maintainable specification. To generate the BPEL service description from π-calculus, one can use the behaviors specified in the process definition within annotations.

While data type definitions in BPEL/WSDL are based on XMLSchema, π-calculus uses processes to represent data. So in order to translate data, one have to identify the related processes from other processes. This can only be done using annotations. Annotations are also used to identify specific BPEL construct or patterns.

To summarize our approach, we first identify data processes, and specific patterns using annotations. We then instantiate activities within proper structured constructs.

4.2. Decomposing π-calculus expressions

We would like to map π-calculus process onto a hierarchical decomposition of specific and adequate BPEL constructs. For example, it is important to identify a sequence of process, though it is represented by a parallel operator and to naturally map it onto a BPEL sequence rather than the more general (and more verbose) flow construct. We must then recognize complex BPEL constructs; we use a bottom up traversal of the parse tree to identify in the π-calculus process, parts that are suitable to BPEL constructs. These block structures are annotated in order to add informations that will help us while choosing the 'good' construct. Annotations will carry all information needed to map a π-calculus expression onto "BPEL block".

4.3. Annotations

An annotation associated with an action stores information (parter link, port type, operation in BPEL, process and action names) on interacting processes. We can add a description of the interaction (e.g. request, notification, cancellation). This information is thus extracted by analyzing associated annotations.

For instance, the following π-calculus processes :

$$P = x(y)_{\{pt:PT,pl:PL\}}$$

will be translated to the BPEL activity :

```
<receive partnerLink="PL" portType="PT" operation="x"
                   variable="y"/>
```

and :

$$Q = \{\overline{x}z\}_{\{pt:PT,pl:PL\}}$$

will be translated to the BPEL activity :

```
<reply partnerLink="PL" portType="PT" operation"x" variable="z"/>
```

The annotation contains also a description of complex activities. For instance, the following expression :

$$R = \{\overline{x}\langle y\rangle.x(z)\}_{\{act:invoke,pt:PT,pl:PL\}}$$

will be translated to the BPEL activity :

```
<invoke partnerLink="PL" portType="PT" operation="x"
       inputVariable="z" outputVariable="y"/>
```

4.4. Translating π-calculus to BPEL

The translation of a π-calculus expression proceeds in a bottom up fashion. First of all we identify relevant expressions and we add the adequate annotation to all nodes of the parse tree; we do this by introducing a pair of squiggly brackets round each possible

$\{0\}$	< invoke partner=" " operation=" " >
$\{\nu x Q\}_{\{fh:FH,eh:EH,cs:CS,ch:CH\}}$	<scope standard-attributes> <variables><variable name="x"/></variables> <correlationSets>CS</correlationSets> <faultHandlers>FH</faultHandlers> <compensationHandler>CH</compensationHandler> <eventHandlers>EH</eventHandlers> activity </scope>
$\{!Q\}$	<while condition ="exp = 'yes'"> <sequence> $< ...activity... >$ </sequence> </while>
$\{Q_1 \mid Q_2\}_{\{act:flow\}}$	<flow> $< ...activity_1... >$ $< ...activity_2... >$ </flow>
$\{Q_1 \mid Q_2\}_{\{act:seq\}}$ or $(Q_1.\overline{y}\langle\rangle \mid y(u).Q_2)$	<sequence> $< ...activity_1... >$ $< ...activity_2... >$ </sequence>
$\{\overline{y}\langle v_1\rangle Q_1 + \overline{y}\langle v_2\rangle Q_2\}_{\{act:pick\}}$	<pick ... > <onMessage ... variable="v_1"> $< ...activity_1... >$ </onMessage> <onMessage ... variable="v_2"> $< ...activity_2... >$ </onMessage> </pick>

Table 3. Translating π-calculus to BPEL

subexpression, and labelling each pair with the annotation. Secondly, we will translate each process subexpression to a BPEL activity.

We assume that all bound variables occurring in the π-calculus expression that we are translating have been renamed apart from each other and apart from any free names in the expression. This forestalls the need to actually invoke alpha-conversion in the translation. A translation table is presented in Table 3.

Translating a sequential composition : A sequential composition is identified by 2 process linked by a parallel operation and one is postfixed by an output and the other one is prefixed by an input on the same channel.

Non deterministic choice : The pick BPEL activity is executed when it receives one message defined in one of its `onMessage` tag or when it is fired by an `onAlarm` event.

We can use the non deterministic choice, in which the first action of each branch is a reception; it is chosen the branch whose beginnig reception is performed first.

5. Example

Here is a part of a tiny example from [1]. A Seller in a system that processes a purchase order is represented in π-calculus as follows :

$$Seller(order, transfert, f) \ = \\ (\nu w)(\nu z)(\nu s_f)(order(po, cc, z)(\overline{transfert}\langle w, z\rangle.0 \ + \ \overline{f}\langle s_f\rangle.0))$$

The Seller receives a purchase order (po), a credit card number (cc) and a channel (z) on the channel $order$, from the Customer. He sends the parcel weight w and a customer channel name z on the channel $transfert$ to the Shipper, or a fault name s_f to the Fault Handler. The process Seller acts as a coordinator in the choreography.

5.1. Annotation

We first add annotations to the specification of the Seller :

$$Seller(order, transfert, f) \ = \ \{(\nu w)(\nu z)(\nu s_f)(\{order(po, cc, z)\}_{\{pt:OPT, pl:Cust\}}. \\ (\{\overline{transfert}\langle w, z\rangle\}_{\{pt:DPT, pl:Ship\}}.0 \ + \ \{\overline{f}\langle s_f\rangle\}_{\{act:fh\}}.0))\}_{\{fh:FH\}}$$

5.2. Translation

Table 4 gives the translation of the Seller process. Note that we use abbreviations for clarity.

6. Conclusion

In this paper we presented an method to generate BPEL specifications from π-calculus processes. While several researchers have been working on translations from BPEL to formal models, we argued that automatically generating BPEL is a promising way. Process algebra allows not only temporal logic model checking, but also a simulation and bisimulation analysis; they allow a design method, hierarchical refinement, that we can apply to WSs. In fact the two-way mapping allow us to design and verify both in process algebra and in BPEL.

The goal of our translation is to generate compact and readable BPEL template code, i.e., we carefully try to annotate π-calculus processes in order to fit well with specific BPEL constructs. This way the BPEL specification remains readable and maintainable. Using a tiny example, we showed the applicability of our approach.

Process algebra allows not only temporal logic model checking, but also a simulation and bisimulation analysis. The two-way mapping allow us to design and verify both in process algebra and in BPEL. We are actually working on definition of a compatibility adapted to WS. It is interesting to extend our work in the following directions : adapt the mapping to other languages onto BPEL. such as the Business Process Modeling Notation (BPMN) [3]. For a more precise analysis, we also need to integrate data considerations in our model.

```
<scope name="Seller">
 <variables>
 <variable name="w"/><variable name="z"/><variable name="sf"/>
 </variables>
<sequence>
 <receive partner="customer" portType="OrderPT"
 operation="Order" variable="PurchaseOrder"
 variable="CreditCardNumber" variable="z" />
 <reply partnerLink="Shipper" operation="Transfert"
 outputVariable="w" outputVariable="z"
 portType="reqDeliveryPT" />
</sequence>
<faultHandler>
 <catchAll>
 <compensate scope="FH"/>
</catchAll>
</faultHandler>
</scope>
```

Table 4. Translation of the Seller process

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Using context to improve semantic interoperability

Patrick Hoffmann, Lionel Médini and Parisa Ghodous *
Lyon Research Center for Images and Intelligent Information Systems
Claude Bernard Lyon 1 University, Villeurbanne, France

Abstract.
This paper presents an approach to enhance interoperability between heterogeneous ontologies. It consists in adapting the ranking of concepts to the final users and their work context. The computations are based on an upper domain ontology, a task hierarchy and a user profile. As prerequisites, OWL ontologies have to be given, and an *articulation ontology* has to be built.

Keywords. context, contextual ranking, semantic resources, semantic similarity

1. Introduction

In an increasing number of organizations, virtual collaboration becomes a reality. More and more collaborative platforms provide means for connecting various models and tools used by different partners of Concurrent Engineering (CE) projects. Computerized data exchanges yet suffer from software incompatibilities, resulting in semantic losses when transmitting high level data. This is particularly true when considering complex data (3D data, simulation data, etc.).

In CE, semantic resources(such as taxonomies, ontologies) are built for specific purposes, and evolve with the projects they are associated to. Semantic interoperability (i.e. interoperability between semantic resources) cannot therefore be achieved by integrating ontologies but by establishing mappings between semantically related concepts from different ontologies. Since semantic interoperability depends on these mappings, it is essential to be capable of evaluating their relevance. As the same mappings are not as relevant for every users and every task, we herein propose an approach to compute a context-based evaluation of such mappings.

Our approach is based on a context model composed of classifications of the organization activity domains and tasks as well as of users' profiles, on OWL ontologies, and on a ranking system. This ranking system receives requests on concepts from the OWL ontologies, made on users' behalf. As results, it returns all semantically related concepts from the OWL ontologies, and ranks them according to the users' contexts. This work is a continuation of Ferreira Da Silva et al.[1] contribution to semantic interoperability with SRILS, a middleware in which the ranking system is intended to be a module.

* {patrick.hoffmann, lionel.medini, parisa.ghodous}@liris.cnrs.fr

The paper is organized as follows: in section 2, we examine different propositions to model context, and other related work that use context to compare semantic associations. Section 3 presents our proposal for modeling context and using it to compare semantic associations. Section 4 discusses our methodology to build context models, and its cost. Section 5 concludes the paper.

2. Related work

2.1. Context modeling

The notion of context first appeared as a major principle in CS in [2], where John McCarthy stressed the high significance of the notion, and proposed a formalization of context as a first class object in logic languages. From Artificial Intelligence (AI) fields (Context Modeling, Problem Solving...), the notion is now being used more widely (Information Retrieval, Ubiquitous Computing...). Several definitions of context have been given [3,4,5], that define context as what is relevant to understand a considered event and its implications. More, Dey notes that the final user should to be taken into account as well.

As we are only interested in modeling context and making computations on it to determine the relevance of semantic associations, we think that powerful AI context models are not necessary to our case. Indeed, we are neither primarily interested in preserving consistency nor in making new assumptions by inferences.

2.2. Contextual comparison of semantic associations

Classic comparisons of semantic associations rely on semantic similarity measures or their inverse, semantic distances. Semantic similarity measures are often distance-based (depending on the number of edges that separate the concepts in a graph) [6,7] or information content-based (assuming that some concepts are more informative than others) [8]. Few attempts have been made to contextualize semantic similarity measures. Rodriguez and Egenhofer proposed to match the users' "intention" to increase the relevance of their measure [9]. Roddick et al. underline the necessity of lying on context-dependent similarity measures [10] when computing a global semantic similarity measure.

Aleman-Meza et al. [11], as well as Nejdl and Paiu [12] propose approaches that compare semantic associations in a contextualized manner, not depending on a typical semantic distance. Aleman-Meza et al. consider all entities related to a given entity by a sequence of links, called "paths". Those are ranked depending on both their "universal" and "user-defined" weights. The latter are added when the path traverses a region that the user has set as being of interest, or a source that the user trusts. Nejdl and Paiu propose an authority-based ranking algorithm destined for desktop search. A "context ontology" describes the relations between the files and how they had been obtained (e-mail, url) and used (file properties). Users describe what makes a file important (namely "authoritative"). Files are ranked by applying "authority transfer weights".

We were inspired by the proposition of Rodriguez et al. [9], which leads us to consider users' tasks. As Aleman-Meza et al. [11], we divide semantic resources into regions, and we plan to consider user confidence.

3. Proposal

Our approach consists in a ranking system, a context model and resources gathered by the organization: OWL ontologies, as well as an articulation ontology which contains mappings that connect semantically related concepts of the different ontologies. The ranking system treats requests on a concept from a given OWL ontology, and returns a ranking of semantic relationships between concepts, based on users' domains and tasks.

Our work hypothesis is that individuals' context may be adequately represented by a profile referencing their activity domains and the tasks that they have to perform. This requires that a classification of domains and tasks be built by experts. For our context models, we thus used the OWL[1] sublanguage OWL DL, since it is standard (W3C[2] recommendation), well supported[3], and widely used for writing ontologies. For a ranking system, response time is critical; we therefore need to do the maximum of the work off line.

Our approach consists in three steps: modeling the context (using three resources), preparing and storing off line computations, and using them to provide a fast ranking of semantic associations at request time.

3.1. Context representation

The **upper domain ontology** (UDO) describes the organization activity domains by relating the most important concepts to one another. We name these concepts *semantic descriptors* (SD). They may be added an XML[4] attribute *related resource* to refer an ontology part[5]. This means that the ontology part is to be interpreted as depending on the (sub-)domain described by the SD. One can also add an attributes *relevant task* linked up to a concept standing for a specialized task, to signify that actors of the (sub-)domain may perform such tasks. Those tasks are referred to in the Task hierarchy by the generic tasks they specialize.

The **task hierarchy** describes tasks in terms of *used tools*, *exploited material*, *needed competence* using XML attributes of that even names, and linked to semantic descriptors. *Specific tasks* may be related to ontology parts, by a *relevant resource* attribute, meaning that the ontology part is interpreted as a relevant resource for performing the task.

The **user profile** is a lightweight hierarchy with three main branches: "general data" where are stored every informations necessary to identify the users when they connect, and allow users to recognize their colleagues; "activity domains" where the users refer the SD corresponding to their activity domains; "tasks" where they refer the TH specific tasks they are used to perform.

3.2. Off-line preparation algorithm

The system computes a semantic similarity measure between OWL ontologies concepts and SD, as well as user tasks. This information is then stored in a database, so as to be able to access to it quickly at request time.

[1]Web Ontology Language, http://www.w3.org/2004/OWL/
[2]World Wide Web Consortium, http://www.w3.org/
[3]see Jena Semantic Web Framework, http://jena.sourceforge.net/
[4]Extensible Markup Language (XML), http://www.w3.org/XML/
[5]An ontology part is constituted by a concept and all its sub-concepts.

For each ontology concept c, we store the $domains(c)$ list of SD that refer any part it is included in. We then associate to each SD a c-dependent likelihood (Eq. 1). Semantic descriptors that do not exceed a given threshold are given the likelihood 0.

We use the notation: $\mathcal{O}$ for the UDO, sd for the semantic descriptors, c for ontology concepts, and t for tasks. The similarity measure *sim* used is asymmetrical, distance-based, and so that $sim(sd_i, sd_j) < sim(sd_j, sd_i)$ if sd_j subsumes sd_i (if c is related to sd_i, there is no evidence that it is also related to a more general concept sd_j). The first equation term is a correction value depending on the concept level of abstraction. It is based on the intuition that the more abstract the domain the user is interested in, the more probable it refer concepts that the user is not really interested in.

$$likelihood_{c,\mathcal{O}}(sd) = \frac{depth_{\mathcal{O}}(sd)}{\max_{i|sd_i \in \mathcal{O}} depth_{\mathcal{O}}(sd_i)} \times \max_{i|sd_i \in domains(c)} sim(sd, sd_i) \quad (1)$$

In the same way, for each ontology concept c we compute a list $tasks(c)$ of tasks that refer any part it is included in. We associate to each task the likelihood (Eq. 2):

$$likelihood_{c,\mathcal{O}}(t) = \sum_{i|t_i \in tasks(c)} sim(t_i, t) \quad (2)$$

3.3. Behavior at request time

Requests sent to the ranking system are all composed of a concept from a OWL ontologies, the user's identifier, and optionally the task that she/he wants to perform. The ranking system retrieves corresponding mappings in the AO, and information from the user profile. For each semantically related concept,it retrieves *likelihood* values for relevant domains and tasks from a database. We herein describe how the ranking system computes these values to obtain an unique value for each concept. This value will serve to rank the concepts in a contextualized manner.

Let a request be made on any user's behalf. Let us name the user's profile $\mathcal{P}$, and the request concept c_0. For each concept c we compute the $sim(c_0, c)$ value. We remove from the ranking the ontology concepts for which SD presents in the user profile are associated to a likelihood of 0. We compute for each ontology concept a measure of its adaptation (Eq. 3) to the profile and to the original concept.

$$adaptation_{c_0,\mathcal{O}}(c, \mathcal{P}) = \max_{i|sd_i \in \mathcal{P}} (likelihood_{c,\mathcal{O}}(sd_i) \times likelihood_{c_0,\mathcal{O}}(sd_i)) \quad (3)$$

The *usefulness* of the concept depends on the presence of related tasks in the user profile. It depends as well on whether there are tasks that are related to both the concept and the original concept.

$$usefulness_{c_0,\mathcal{O}}(c, \mathcal{P}) = \max_{i|t_i \in \mathcal{P}} (likelihood_{c_0}(t_i) \times likelihood_c(t_i) \times sim(c_0, t_i))$$

Finally, we rank the concepts depending on the value:

$$adaptation_{c_0,\mathcal{O}}(c, \mathcal{P}) \times usefulness_{c_0,\mathcal{O}}(c, \mathcal{P}) \times sim(c_0, c)$$

4. Functioning of the ranking system

This section shows an example of how the ranking module works, using three ontologies from the construction domain. The first one classifies a list of enterprises (Fig 1), the second one describes the domain of an organization specialized in reinforcing concrete (Fig. 2), and the third one is an ontology of concrete Fig. 3. An articulation ontology is built from these ontologies (Fig. 4).

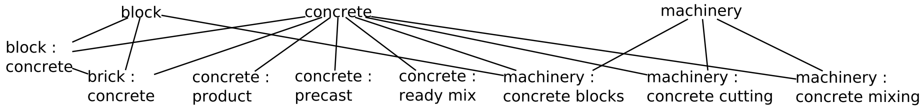

Figure 1. ontology yellowpages

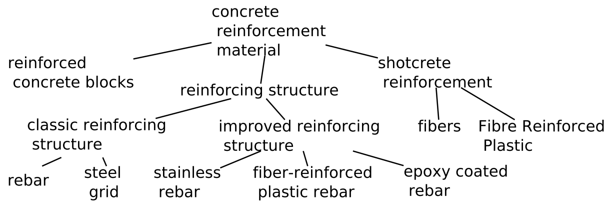

Figure 2. ontology reinforcing concrete

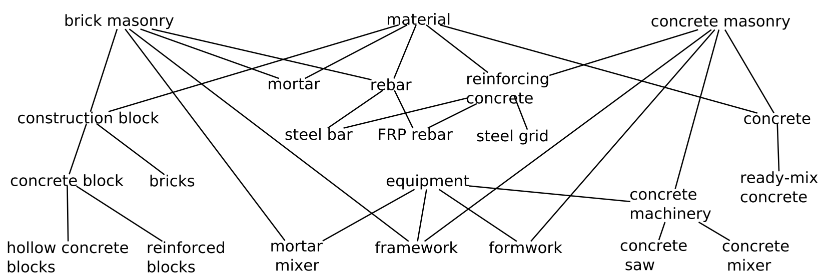

Figure 3. ontology concrete encyclopedia

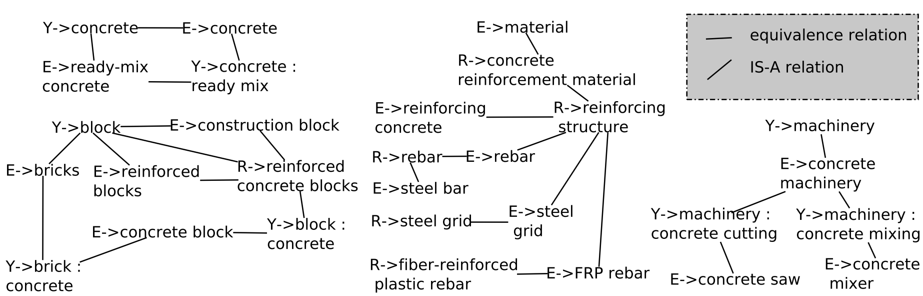

Figure 4. part of the articulation ontology

4.1. The contextual resources

We based our upper domain ontology (Fig. 5) on the UDC outline [6]. Our methodology to construct it was to first isolate the different principles of construction (here *brick masonry* and *concrete masonry*) that utilize different methods and tools. Then, we separated the concepts depending how they are employed (*material* and *equipment*). Finally, the most general concepts are chosen to be SD, and represented in the figure.

To construct the task hierarchy, we first summed up the masonry main task in a single verb (*build*), and we developed in by asking the question "how". We did not represent all the possible tasks here, for lack of place. Tasks are represented by a verb, plus a qualified direct object when necessary (e.g. to assemble by sticking, we need to have a *sticking* substance). Then, we linked these generic tasks with specialized tasks, which we put also in the UDO, so as to link them up to the concepts they are semantically related to. Finally, we inserted links to ontology concepts.

Users' *profile* can be based on a domain-specific default profile. It is a repository where the users describe their work environment and detail their work tasks. They may define public parts, so as to share knowledge with their co-workers.

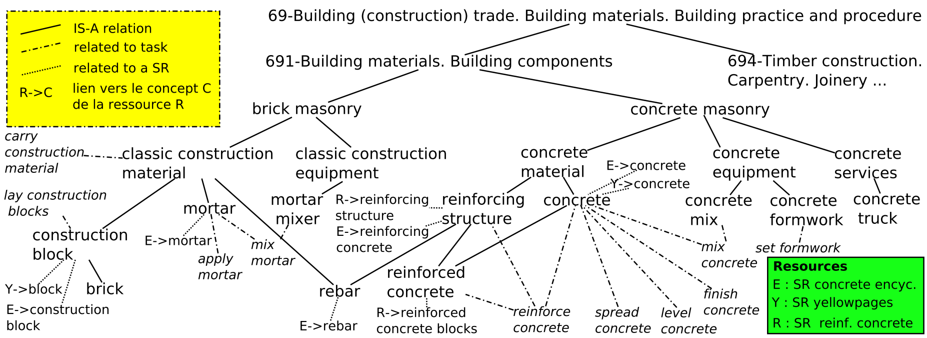

Figure 5. Upper domain ontology

Let Tom be a mason, and let him describe his domains of competencies as being *691-Building materials. Building components* and *693-Masonry and related building crafts*. His profile groups general data to identify him, and references his domains and tasks.

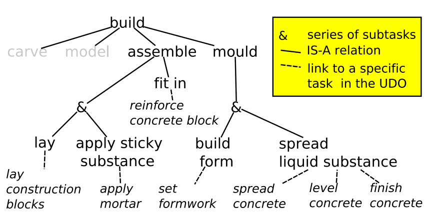

Figure 6. part of the Task hierarchy

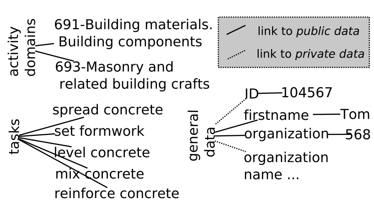

Figure 7. Tom's profile

[6]UDC consortium, see http://www.udcc.org/

4.2. Tom's request

Let Tom query the system with the concept c_0, *reinforcing concrete*, from the ontology "concrete encyclopedia".

The system retrieves all related semantic relationships, from different domains. To reduce complexity, we have not represented the related relationships defined on resources from domains such as *694-Timber construction. Carpentry. Joinery*, *Heating, ventilation and air conditioning of buildings*, etc.

The system filters out the concepts that correspond to the user's selected domains. We thus have: c_0 *is equivalent to* $R \rightarrow$ reinforcing structure, c_0 *generalizes* $E \rightarrow$ rebar, $R \rightarrow$ rebar, $E \rightarrow$ steel grid, $R \rightarrow$ steel grid, $E \rightarrow$ FRP rebar, $R \rightarrow$ fiber reinforced plastic rebar, $E \rightarrow$ steel bar; c_0 *is a* $R \rightarrow$ concrete reinforcment material, c_0 *is closely related to* $R \rightarrow$ reinforced concrete block, $E \rightarrow$ reinforced block.

Tom's profile refers to specific tasks as *spread concrete* and *reinforce concrete*. Only the latter is significant for the concept considered. The order of relationships is not modified, but the three last concepts are no more considered, the ranking is now: c_0 *is equivalent to* $R \rightarrow$ reinforcing structure, c_0 *generalizes* $E \rightarrow$ rebar, $R \rightarrow$ rebar, $E \rightarrow$ steel grid, $R \rightarrow$ steel grid, $E \rightarrow$ FRP rebar, $R \rightarrow$ fiber reinforced plastic rebar, $E \rightarrow$ steel bar.

Tom's request indicates that he is interested in performing the task *assemble*. Specific subtasks are *lay construction blocks* and *apply mortar*. Thus, concepts from the yellowpages ontology and with $Y \rightarrow$ block as an ancestor, or concepts from the concrete encyclopedia ontology with $R \rightarrow$ construction block as ancestor are considered as particularly relevant. Finally, the relationships c_0 *is closely related to* $R \rightarrow$ reinforced concrete block, $E \rightarrow$ reinforced block are returned as most probable, followed by c_0 *is equivalent to* $R \rightarrow$ reinforcing structure, c_0 *generalizes* $E \rightarrow$ rebar, $R \rightarrow$ rebar, $E \rightarrow$ steel grid, $R \rightarrow$ steel grid, $E \rightarrow$ FRP rebar, $R \rightarrow$ fiber reinforced plastic rebar, $E \rightarrow$ steel bar.

5. Conclusion

The approach presented in this paper consists in classifying resources depending on domains and tasks, and in using this even classification to rank concepts according to a user request: first, by filtering out the concepts defined in resources that correspond to user's domains; second, by sorting them depending on their usefulness for the user's current task.

The originality of the approach resides both in the proposal of an user-adapted semantic similarity measure to rank concepts and in the attempt to consider work tasks as a means to sort concepts depending on their usefulness.

We are now working on a prototype that implements our approach. As prospects for the future, we intend to improve our semantic similarity measure, in order to take into consideration the granularity differences between parts of the given ontologies.

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An Ontology-based Approach for "Procedural CAD Models" Data Exchange

Samer ABDUL GHAFOUR, Parisa GHODOUS, Behzad SHARIAT, Eliane PERNA[1]
LIRIS, University Claude Bernard, Lyon I
43, Bd. Du 11 novembre 1918
69622Villeurbanne Cedex, France

Abstract: In the Concurrent Engineering environment, the interoperability of various CAD systems requires maintaining the design intent. In this paper, we present an ontology based approach as a mean for semantic data exchange in engineering design area. Our purpose is to provide capabilities to transfer procedural model data including the design intent. The devised approach consists of developing generic feature-based design ontology in addition of specific design ontologies for CAD systems. Concepts defined in our ontology include parts, features, constraints, history of construction. Interoperability among ontologies is fulfilled by defining several mapping rules. We use descriptive logic language, notably OWL to represent formally our ontology.

Keywords: Collaborative design, CAD, CAD, Design Knowledge, Feature, Interoperability, Semantic Exchange, Neutral Format, STEP, Ontology

Introduction

For product development process, economic growth and cutthroat competition among companies involve reducing the time-to-market and improving the quality of design using CAD/CAM. Recent research works and developments aim to substantially improve product quality and reliability by integrating many activities such as design, analysis, process planning, assembly planning, manufacturing, and inspection. However, corporations must be able to react to the changing market needs rapidly, effectively, and responsively. Therefore, "Concurrent Engineering" strategy has emerged as a way of bringing rapid solutions to product design and development process. To collaborate and communicate effectively, designers must be able to easily and accurately share their MCAD (*Mechanical CAD*) data and related information. Furthermore, this integration of CAD/CAM processes requires the data to be complete and precise. Features are devised to carry, semantically, product information throughout its life cycle [1]. Consequently, features should be maintained in a part model during its migration among different applications or while switching systems at the same stage of product life cycle, e.g. CAD design.

Yet the representation and management of features are problematic in CAD exchanges. Due to the large variety of CAD systems in the market, data exchange among different CAD systems is indispensable [2]. Current tools for product data exchange have been proven as excellent for sharing geometry and topology, whereas design intent is completely lost during the translation process [3]. Once the feature-based CAD model created in one CAD system is input into another via data exchange standards, like STEP (*Standard Exchange for Product data*) or IGES (*Initial Graphics*

[1] {samer.abdulghafour, ghodous, behzad.shariat, eliane.perna}@liris.cnrs.fr

Exchange Specifications), many of the original features and the feature-related information may not exist any longer. In some cases, intelligent model is absolutely required, and thus the model should be recreated. The main problem arisen during the current data exchange systems is that they don't have the possibility to exchange editable procedural models among the CAx systems. So, the CAD data cannot be handled efficiently along the product development process. In this paper, we tackle procedural CAD model data exchange and propose an ontology that captures features semantic. The main objective of our ontology is to enable the transfer of intelligent CAD models among different systems, keeping the design intent of the procedural feature-based model, viz. maintaining the original relations among entities of the model, which can be easily edited or modified. However, it is not the intention of this article to introduce a complete ontology for features or shapes, but to illustrate the beneficial synergy between feature technology and ontology-based approach.

In section 1, we identify issues pertaining to feature-based modeling introducing a formal way of representing the underlying knowledge. In section 2, we present a survey of the current data exchange mechanisms via the standard neutral format, namely STEP. The benefits of "Interoperability" using 'ontology' approach will be revealed in section 3. Then, we define our approach of exchanging design intent in the section 4. This approach yields a generic design-feature ontology which is stated in section 5. Some conclusions are drawn at the end of this paper.

1. Feature-based modeling

There are mainly two approaches for obtaining a feature-based model, that is, feature recognition and feature-based design [4]. In feature recognition, features are automatically or interactively, i.e. by human assistance, extracted from a geometrical model of the object. In the feature-based design approach, designers are able to model parts using pre-defined features primitives, and a geometric model is generated from the resultant feature model. Regarding the design intent, the recognition approach, dealing solely with geometric model, causes the loss of all non-geometrical data attached to the designed object, whereas the feature-based design allows handling feature information of the part components and its attached semantics. More importantly, since individual features are distinctively represented in the system, they can be edited, manipulated and graphically verified. Hence, we are interested in translating feature-based models created with the feature-based design approach. In the feature-based design approach, constraints are managed by two generic approaches: procedural and declarative [5]. In the procedural approach, features are sets of procedures where features constraints may be buried inside the procedures, while in the declarative approach, features are sets of constraints. The procedural approach is dependent on the construction history of the model. However, the procedures sequence enables to generate the explicit data, namely its B-Rep scheme depicted in terms of vertices, edges and faces. Due to its widespread use within modeling systems, the procedural approach constitutes an effective issue of interest in our approach.

2. Feature's Interoperability via standards (STEP)

There are two major mechanisms for product data exchange [3]: direct and indirect i.e. through a neutral format. Various neutral formats, e.g. STEP [6], IGES, and DXF have proven successful in the exchange of product geometry on a high quality level. Nevertheless, the problem consists in the ability of editing the outset model in the

target system. Indeed, design intent including constructional operations history, parameters, constraints, and features are potentially lost [3]. In other words, models exported from CAD systems in neutral format standards come into systems as featureless chunks of geometric entities, with less information that was originally embedded in the original features.

CAD data exchange problem is highly addressed by the international standard ISO 10303 or STEP which provides a system independent format for the transmission of data, in computer interpretable form, between different CAD systems, or between CAD and other computer-based engineering systems [8]. First parts of STEP were published in 1994, with a limited scope. Since that time, the standard has been under continual development to widen its coverage by the addition of further capabilities[2]. The initial release of ISO 10303 was aimed entirely at the exchange of explicit models, defined in terms of geometry, possibly with additional topological information providing connectivity relationships between geometric elements. To cover design intent exchange, STEP schema is under development to be extended in order to include the history-based model and the parameters in the procedural model adopted by commercial CAD systems.

Recent developed resources of ISO 10303 are intended to mainly support the transfer of the design intent, namely part 55 (*Procedural and Hybrid Representation*) [12], part 108 (*Parameterization and Constraints for explicit geometric product models*) [13], and the part 111 (*Construction History Features*) [14]. The part 55, recently published as international standards, provides basic mechanisms for procedural or construction history modeling. Thanks to this resource, the correct order of operations sequence is handled, since the same set of construction operations performed in a different order usually gives a different shape model. A further important aspect of ISO10303-55 is that it associates the procedural or hybrid model with the explicit model. A hybrid model is a basically procedural model also containing explicit geometric elements [8]. The part 108, also recently published as international standard, in a new STEP resource providing representation of parameters, explicit constraints, and explicit 2D sketches or profiles. However, new entities should be defined to represent the powerful feature-based operations available in the user interfaces of all major CAD systems. A new resource ISO 10303 – 111 is developed to fill this requirement. It has been written to provide representations for the required high level constructional operations [8]. The extension of entities currently available is highly required to correspond to the feature-based modeling operations provided by CAD systems. The highest level selection of shape features defined in ISO 10303-111 includes holes, pockets, slots, grooves, and general protrusions. Below this level, there are defined many specialized subtypes. For example, subtypes of the hole feature include blind holes, and through holes. Other capabilities provided in this resource allow the creation of solids with blends, shelled solids, and solids exhibiting patterns of simple features. However, STEP doesn't enable representing dynamically product data [10]. "Ontology" approach can be exploited in order to enhance capabilities of interoperability among CAD/CAM systems.

3. Ontological Interoperability

In order to enhance interpretability efficiency in a specific domain, semantics assigned to data and context in which data are viewed and interpreted should be explicitly declared [11]. Different representations of the same information might bring

[2] Recent updates and details can be found at : http://www.tc184-sc4.org/

out various concepts and terminologies, and conversely, the same term used in different contexts may designate different concepts. Thus, a great deal of efforts has been made by researchers and developers to define sharable models namely "Ontology". Ontology is a formal declarative specification of concepts and their properties, relationships, and constraints, intended for use in knowledge sharing in a particular domain [7]. Concepts of the domain are linked to each other by relationships that carry a semantic meaning. With this means of knowledge modeling, the semantics of the domain can be made explicit in a declarative way, making it accessible for machines. Furthermore, explicit knowledge can be used as input for reasoning algorithms in order to deduce implicit knowledge, i.e. statements that have not been explicitly modeled.

Ontology formality in the specification of meaning is expressed with respect to a language in which ontology is represented. Ontologies, declarative semantics, and reasoning are ubiquitous in current semantic web research, where ontology description languages have emerged and are currently being further specified and standardized. The most significant among them is the RDF (Resource Description Framework) standard together with its extension RDFS (RDF Schema) both introduced by the W3C consortium. On top of RDF(S) several other standards have been introduced like DAML+OIL or OWL [9] which extends RDF(S) by a richer model-theoretic semantics imposing certain implications and constraints on predefined language constructs.

4. Ontological Approach

Our approach is based on using the ontology mechanism as neutral format for procedural models data exchange in order to confront limitations of STEP. It consists of defining a design feature ontology containing features commonly used by the most of CAD systems. This enables designers to communicate with the system on higher abstraction level, such as holes, pockets, grooves, than lower geometric entities, as vertices, edges, faces, etc. Consequently, each application requires merely one translator between the application's terminology and the common features ontology. A schema illustrating our approach is represented in the figure I.

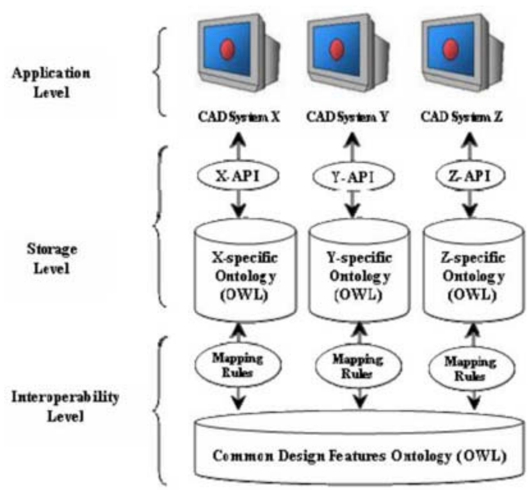

Figure I. Scenario of "Ontology-based" approach

As indicated in the figure I, the structure of our approach is comprised of three levels: application, storage, and interoperability. At the application level, users create a product procedural model using a feature-based CAD system. Current feature modeling

systems do provide the user with "engineering rich" dialogs aimed at the creation and manipulation of feature instances. In such systems, the resulted procedural model maintaining high level defined entities is stored in a system-specific format. At the storage level, we associate an ontology to each CAD application. The essential purpose of such an ontology is to represent not only design feature classes provided by the CAD system, but also their attributes and constraints defined as relationships between the defined concepts. Thus, analysis of CAD systems is required. Once the ontology is created, the resulted procedural model could be instantiated.

The communication of data between the stored format and the ontology instance is essential. This issue entails retrieving the design features data from the CAD system format, then developing the ontology instance accordingly. Accessing to procedural model data, stored in a system-specific format, is carried out by using application specific APIs provided with the system or via libraries developed by some CAD translators. These functionalities allow retrieving the needed information of the procedural model, namely the history of construction, high level entities, parameters, and constraints.

At the third level, the interoperability issue among the different resulted ontologies of the previous levels is examined. Based on the neutral format mechanism, our approach is fundamentally depending on the creation of common design features ontology. A set of design features issued by a CAD user is defined as the procedural model components, which include the designer's intent. However, the definition and development of this common design ontology features will be detailed in the next section. At this level, mapping between the users' ontology instances and the common design ontology occurs. Furthermore, ontologies interoperability requires developing of mapping rules, a substantial mechanism to take a heed of heterogeneity issues. These rules should be set between the application-specific ontologies, for CAD systems, and the common features design ontology.

To avoid heterogeneities at the language format level, we have opted for the OWL language to formalize the design-feature ontology with textual format wising a formal ontology language. Our preference of OWL is relied on many reasons. The structure of OWL language permits defining concepts as classes, explicit semantic relationships and to create instances of defined model. Besides, the OWL syntax is based on XML, thereby the descriptions encoded in this language can be operated on by automated retrieval and analysis processes. Another critical factor of adopting OWL is its acceptance by the market. Research and developments based on OWL are widely supported by both academic and industry. Moreover, open-source tools are available, e.g. Ontology Editor provided by Protégé[3].

5. Design features Ontology

Firstly, we will premise in this section the issue to be exchanged in a procedural model, notably the design intent. Following Bill Anderson's definition [15], we define the term design intent as "some functional requirements provided by customers, that is, a set of geometric and functional rules which the final product have to satisfy". Therefore the design intent is represented by constraints, parameters, design history, and features. To build our design features ontology, our methodology consists of the following steps: (1) Provide a terminology that can be shared by the design engineers. This enables using the same terminology so they can work in the same level and achieve high level collaboration. (2) Define the relations existing among the various

[3] http://protege.stanford.edu/plugins/owl/protege-owl-faq.html

concepts to explicit the meaning of each concept, thus give a precise and unambiguous semantics for each concept. Accordingly, possible conflicts could be avoided. (3) Represent graphically the concepts already defined at the first step, as well as their relationships. This step permits to visualize the set of concepts forming the ontology, and especially relations between them. (4) Represent formally with the ontology language OWL, the outcome of the previous steps. The term formal indicates that the outcome ontology is machine-comprehensible.

We surveyed the modeling features of three commercial CAD systems, namely CatiaV5[4], Pro/engineer[5] and SolidWORKS[6] to retrieve the common user modeling features of CAD systems. However, this set is not intended to be exhaustive and more concepts could be added increasingly. These extracted concepts constitute the terminology of the constructed ontology in the design domain. In the subsequent sections, we will provide a schema for our ontology. Thereafter, a subset of this ontology schema will be defined formally with OWL ontology language.

5.1. A schema of the "design feature ontology"

Our ontology schema, illustrated in fig. II, concern not merely geometrical data, but also technical information related to the part, or the assembly representing the product. Concepts retrieved from CAD systems are represented as classes and their several types of relationships are defined. Firstly, class hierarchies are created by making that a class is a subclass of another class. For example, the class "FirstArtifact" is stated to be a subclass of the class "ArtifactSequence". Secondly, semantic binary relationships are defined between two classes such as "hasMainBody" which relates a boolean operation instance to the main specific body. An important aspect of our ontology is its ability to store the history of construction as far as the order of the arguments is highly meaningful.

The main class of this ontology is a "Product" which is associated to a version. Each product is composed of an ordered sequence of artifacts, i.e. assemblies or parts, and is referred to a set of units. The term units is important to define the measurements units used in the ontology and which differs according to various areas, e.g. inches or meters. The class "ArtifactSequence" stores the constructional ordered sequence of artifacts, and instances are related with the property "nextArtifact". "FirstArtifact" and "FinalArtifact", subclasses of "ArtifactSequence", represent respectively the first and the last created artifacts. Note that "FinalArtifact" is defined with a maximum cardinality of 0 on the "nextArtifact" property, to indicate the end of the sequence. An artifact has a material and referenced to a coordinate system datum. Each artifact in turn could be composed of an ordered sequence of bodies. A body is in turn defined by an ordered sequence of design operations characterizing the shape of this body. An operation could be either a feature applied to a body or a boolean operation applied to two distinct bodies such as add, remove, or intersect.

A fundamental class of our ontology is "Feature" which constitutes a subset of the form of an object that has some function assigned to it. The "Function" represents what the feature is supposed to do. The feature satisfies the engineering requirements largely through its function. The form of the feature can be viewed as the proposed design solution for the requirement specified by the function. There is a need to handle geometrical entities that constitute the feature, a created face for instance. For this reason, a feature element is added to our ontology. A set of feature element is defined

[4] http://www.3ds.com/products-solutions/plm-solutions/catia/overview/
[5] http://www.ptc.com/appserver/mkt/products/home.jsp?k=403
[6] http://www.solidworks.fr/

in the part 48 of STEP [16]. These elements are considered to be of dimensions 0, 1 or 2 that referred to vertices, edges, and faces respectively. We can have several types of features: analysis features, design features, manufacturing features, interface or port features, etc. Compound features can be generated from primitive features and is related to its sub-features with the property "hasSubFeature". The geometrical representation of the feature is represented through the class "Feature Representation". It describes the way the feature is represented, such as B-Rep, CSG, etc. A general definition of feature representation is also defined in the part 48 of STEP.

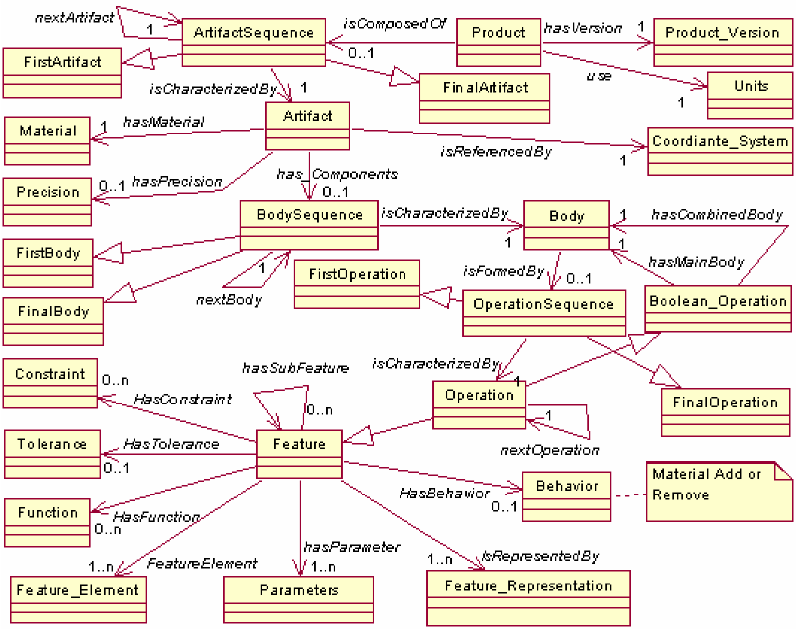

Figure II. General View of the common design features ontology

Other aspects related to a feature are constraints, parameters, tolerance, and behavior. Each feature could have many constraints applied among elements of the same feature or between two distinct features. A detailed description of constraints is carried out in [11]. Besides, a tolerance is associated to a feature to represent variational part of the product. Parameters are crucial data that should be represented and associated to features. Parameters are specific to each type of features, e.g. a hole could be defined by a depth and a radius. Some parameters could be non geometrical such as the norm associated to a defined hole characterizing its attributes.

5.2. Formal Representation with OWL ontology language

Based on the ontology schema built in Section 5.1, a shared reference ontology in OWL has been defined to provide an integrated conceptual knowledge model for sharing design information and semantics in heterogeneous applications of CAD. Figure III shows a segment of the ontology for a definition of the concept "*Body*" in Figure II. "*owl:Class*" construct enables representing a generalized type or defining a type of objects. Each class can be further divided into subclasses, denoted with "*rdfs:subClassOf*". For instance, "FinalOperation" is a subclass of "OperationSequence". An OWL property (i.e. *ObjectProperty* or *DatatypeProperty*) is a binary relation to relate an OWL class to another one, or to RDF literals and XML

Schema datatypes. "*owl: ObjectProperty*" is used to relate instances of two classes e.g. "nextOperation". "*owl:DatatypeProperty*" is used to relate an instance of a class to an instance of a defined type (integer, string, date) e.g. the radius of a hole. The domain and range pairs defined for a property restrict these relations to the concerned classes. For example, the "isFormedBy" property relates an instance of the "Body" class to an instance of the "*OperationSequence*" class; "*FunctionalProperty*" is a property type that can have only one (unique) value in the range class for each instance of the domain class. Described by these formal, explicit and rich semantics, design features classes, their properties and relationships with other concepts can be queried, reasoned or mapped to support the product semantics sharing across product lifecycle.

```
<owl:Class rdf:ID="OperationSequence">
   <rdfs:subClassOf rdf:resource="http://www.w3.org/2002.07/owl#Thing" />
   <rdfs:subClassOf>
      <owl:Restriction>
         <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int">1</owl:cardinality>
    <owl:onProperty>
               <owl:ObjectProperty rdf:about="#isCharacterizedBy" />
          </owl:onProperty>
         </owl:Restriction>
   </rdfs:subClassOf>
   </owl:Class>
   <owl:Class rdf:ID="Body" />
  <owl:Class rdf:ID="FinalOperation">
   <rdfs:subClassOf rdf:resource="#OperationSequence" />
  <rdfs:subClassOf>
     <owl:Restriction>
         <owl:onProperty>
               <owl:FunctionalProperty rdf:ID="nextOperation" />
         </owl:onProperty>
           <owl:maxCardinality  rdf:datatype="http://www.w3.org/2001/XMLSchema#int">0
         </owl:maxCardinality>
       </owl:Restriction>
      </rdfs:subClassOf>
</owl:Class>
<owl:ObjectProperty rdf:ID="isFormedBy">
   <rdfs:range rdf:resource="#OperationSequence" />
   <rdfs:domain rdf:resource="#Body" />
   <rdf:type rdf:resource="http://www.w3.org/2002.07/owl#FunctionalProperty" />
</owl:ObjectProperty>
<owl:ObjectProperty rdf:about="#isCharacterizedBy">
      <rdfs:domain rdf:resource="#OperationSequence" />
      <rdfs:range rdf:resource="#Operation" />
      <rdf:type rdf:resource="http://www.w3.org/2002.07/owl#FunctionalProperty" />
</owl:ObjectProperty>
<owl:FunctionalProperty rdf:about="#nextOperation">
      <rdf:type rdf:resource="http://www.w3.org/2002.07/owl#ObjectProperty" />
      <rdfs:range rdf:resource="#OperationSequence" />
      <rdfs:domain rdf:resource="#OperationSequence" />
</owl:FunctionalProperty>
```

Figure III. OWL code for the "Body" concept.

6. Conclusion

We have proposed an ontology-based approach for explicitly specifying, capturing, interpreting, and reusing the product semantics to facilitate heterogeneous information sharing across CAD systems. The designed ontology defined maintains the links among high level entities (features), besides relationships with lower level entities (geometric or topological entities) which enable CAD models to be edited in the receiving system following a transfer just as if they had originally been created there. It provides an unambiguous and precise terminology such a way that design engineers can jointly understand and exchange CAD models more efficiently at high level. However, to set up a feature based translation, it is crucial to generate a feature mapping which is not a trivial task. Each MCAD design system has its own representation of each feature. Some features are simple and can easily be mapped to other MCAD systems, but some are complex. Thus, one must define a procedure to

identify the features to be mapped in various MCAD systems. This task needs lot of experience and costs a long time.

As a result, the feature-based translation tools can be relatively expensive to implement. Our structure is generic, reusable, and easy to extend. For instance, manufacturing data could be handled in order to bridge the gap between CAD/CAM systems. We use a descriptive logic language, notably OWL to define formally our ontology, in order to define the concepts, their properties and their potential interactions. Given such an ontology, the OWL formal semantics specifies how to derive its logical consequences, i.e. facts not literally present in the ontology, but entailed by the intrinsic semantics handled by the ontology. The future efforts will be focused on ontology reasoning and matching issues to support more effective sharing of product semantics across heterogeneous lifecycle processes.

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Knowledge in CE

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Knowledge Acquisition for Generative Model Construction

Wojciech SKARKA
Silesian University of Technology, Department of Fundamentals of Machinery Design
Konarskiego 18a, 44-100 Gliwice, Poland
e-mail: wojciech.skarka@polsl.pl

Abstract. Generative Model of a product constructed in CAD system integrates knowledge which is necessary for designing process and product modeling. Such a model in CAD system environment can be treated as KBE application. There is a lack of methodological guidelines for creation of such models, including the whole process of creation from data collection and acquisition to modeling in CAD environment. The paper presents briefly methodology of creation of such a system. The solution for the process of knowledge acquisition for this model has been suggested, including the aspects of the very product, designing process and the usage of a given CAD tool.

Keywords. Generative Model, Knowledge Acquisition, CAD, CATIA, Knowledge Based Engineering

Introduction

CAx tools and in particular CAD (Computer Aided Design) ones have been used in designing processes of machines and devices for many years. In the course of their development many problems were overcome and these solutions marked the milestones in development and at the same time new quality of these systems' usage. Parameterization, 3D geometrical modeling or team work can be mentioned as examples here. Nowadays they form well-accepted standards not only in CAD systems but also they are present in the whole process of product development and what is more they form the basis and it would be difficult to think of the process without them. Ordered and systematic knowledge application forms current problem in product development process. It is especially important in its usage for machines and devices designing because designing processes are of innovative character and decisions taken at the designing phase have positive or negative influence on the whole life of a designed machine or a device. Due to the importance and peculiarity of these issues a new branch has been created, namely Knowledge Based Engineering (KBE) [1], [2], which covers the usage of knowledge in designing processes.

KBE systems have not been used as commonly as earlier CAD ones yet. Bidirectional development of works on the KBE systems can be noticed [3]. On the one hand new systems are being developed and on the other hand knowledge representation tools are integrated to theses systems, based on commonly used CAD systems by means of their natural development. ICAD system [4], which has been used for a few years, belongs to the first of the above mentioned group. However, the usage of newly created KBE systems interferes with well-established standing of CAD systems and

groups of their users. Therefore, the improvement of existing CAD systems in that direction seems to be promoted by not only producers but also the users of theses systems.

1. The idea of a generative model

Current CAD systems commonly use geometrical models of solid or surface type for the purpose of representation of a developed product. These models sometimes, by means of the usage of advanced parameterization techniques, represent products' families rather than single products. Generative Model forms a further extension of 3D geometrical CAD model and thus as far as quality is concerned it marks a big step forward in knowledge integration for parametrical CAD models. The idea for that model is the integration of knowledge geometrical model, which is necessary for designing an instance product of a given class of products [5], [6]. Generative Model for given functional features of a future product 'is able to' determine, by means of knowledge integrated in it, designing features of a product which means automatic generation of a geometrical model after having fed assumed functional features.

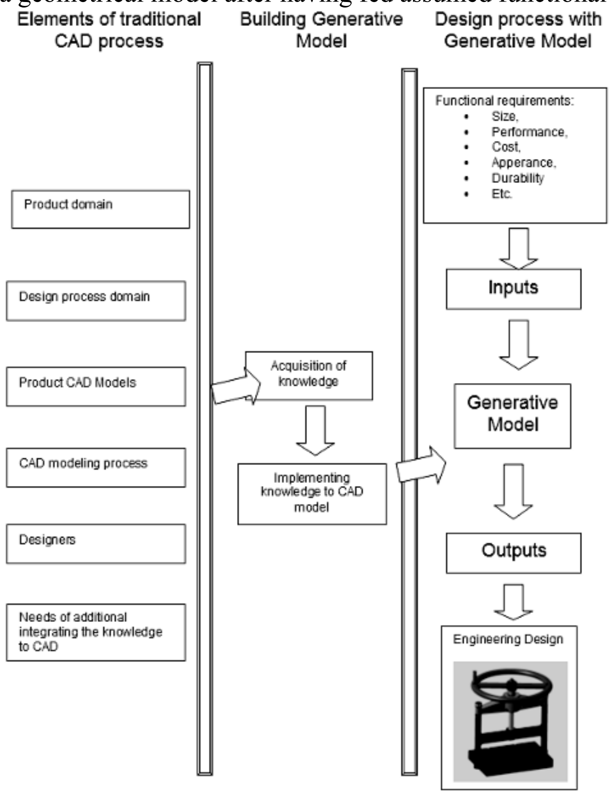

Figure 1 The process of generative model creation and mode of operation

Generative Model itself can reflect description of product class at different level of detail e.g. allowing generation of concept design which would constitute an answer to an enquiry. Such a design forms a base and significantly decreases time and work costs of enquiry preparation but at the successive phases of designing it requires further

detail work by designers. On the other hand it can be used for a part of designed product by means of using some design subassembly in various versions e.g. subassembly of drive transfer or exhaust systems for cars.

The conducted research allowed identification of phases of Generative Model construction and elaboration of methodology of their construction. According to that methodology, construction of Generative Model is a natural consequence of designing process which is carried by means of existing up to now aiding methods in accordance with identified designing process (Figure 1). The existence of product models recorded in CAD and full identification of designing process are a principal condition [7] for making a decision of constructing Generative model. They form indispensable knowledge sources for knowledge acquisition.

2. Problems about knowledge integration to CAD systems

The existing CAD/CAM systems are equipped with sets of functions for knowledge implementation to geometric model which is being built. They make it possible for an experienced designer to construct a generative model. The very model is constructed based on designer's own experience and knowledge or in teams which have been formed for that purpose. Among main problems one can mention technical problems resulting from the usage of these functions, geometrical model stability, shape and form of model and knowledge record etc. Less attention is paid to careful knowledge acquisition for model creation and its proper structuring, classification and record, which with complex designs influence greatly the quality of Generative Model. What is more for obtaining and collecting knowledge regular and systematic methods of conduct or aiding tools do not apply, which is understood since CAD systems are not equipped with them.

3. Construction of knowledge acquisition system for Generative Model

While constructing Generative Model, knowledge from many different ranges is used and the most important among them are [6], [7], [8]:

- The domain of a designed machine/device
- Designing process
- Geometric modeling process with the aid of a given CAD tool

Such a wide range of knowledge, which is necessary for constructing generative model, needs special system of knowledge acquisition and recording. Such system should assure identification, acquisition and recording of such a wide range of complex character and at the same time it should classify and order knowledge by means of both simple and clear interface. This simple knowledge division and clear interface should significantly facilitate these preparatory works for generative model creation. Complex concept of knowledge base can increase workload needed for Generative Model creation, which is incommensurable to potential benefits. It has been chosen to elaborate own methodology [5], [6], [7] of Generative Model. In knowledge acquisition part it has been decided to use Informal Model from MOKA methodology [8] as a framework since it meets basic assumptions, introducing simple conceptual model based on ICARE forms (Illustrations, Constraints, Activities, Rules, Entities).

3.1. Methodology

Newly elaborated methodology, despite the fact that it uses main extracts and assumptions of MOKA methodology [8] by means of using elements from other methodologies concerning designing [9], but also more general ones [10], [11] [12], differs from any of them significantly The MOKA methodology itself admits usage of Informal Model for knowledge acquisition and based on that knowledge construction of Formal Model, which is more complex model used in creation of KBE application itself. In the presented approach Formal Model creation is pointless because desired Generative Model is built by means of CAD application and it plays a role of KBE system in the environment of a given CAD application i.e. it integrates acquired knowledge by specific functions available in CAD application. Therefore, Generative Model plays a role similar to Formal Model from MOKA methodology. Some additional requirements for Informal Model itself result from this situation, as it is necessary to extend this model with knowledge on construction of generative model in a given CAD tool environment. This knowledge is of a specific character and is oriented to special CAD tools and its functions aiding creation of Generative Model, as opposed to universal character of the remaining part of Informal Model (designing process and rules controlling the process, the structure of designed object and constrains describing structure features). This part of Informal Model is independent from the used CAD tool. The way of acquiring knowledge on modeling in CAD system must assure coherence of a structure model of a designed object and CAD structure and at the same time guarantee autonomy of these parts of knowledge base. It gives a possibility to include knowledge on creation of generative model in different CAD systems independently.

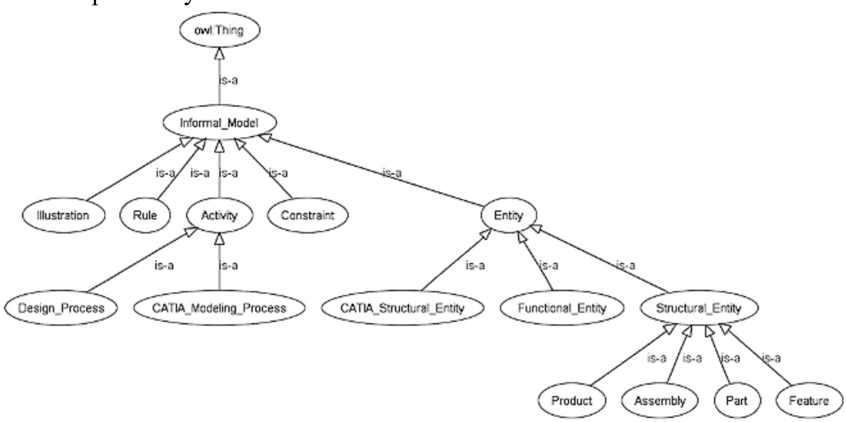

Figure 2. Scheme of main elements of knowledge base metamodel for Generative Model including individuality and autonomy of CAD system

Obtaining knowledge forms a preliminary phase of creating Generative Model, after that the knowledge is successively transferred to Generative Model being built. Thus, further process is CAD application oriented. The aim of the research was to elaborate and test Generative Model construction in CATIA system [13] as one of the most advanced CAD/CAM systems which has separate functions for knowledge integration and automation of geometric model creation. Most of these tools are gathered in Knowledgeware module of the system. In this part of methodology, which is specific for CATIA system, there is a possibility to create generative model in two

ways: either by direct usage of Knowledgeware tools or by Application Programming Interface of CATIA system. For the latter solution it is possible to use separate applications [14] or to use inbuilt mechanisms of automation, which relay on specialized programming languages. Another option is to use Visual Basic. Figure 3 presents the scheme in the whole of methodology together with a part which is exclusive for CATIA system.

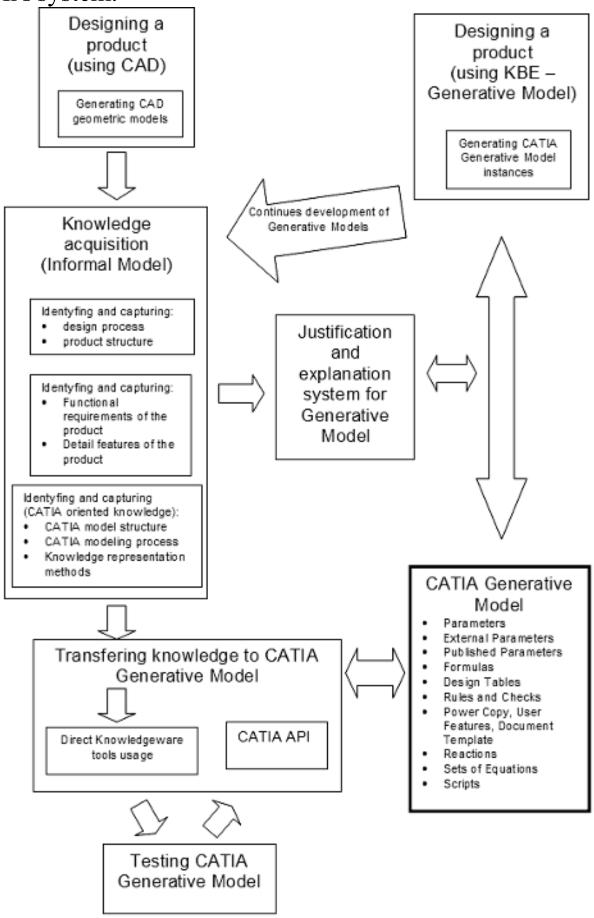

Figure 3. The phases of methodology of Generative Model creation (CATIA oriented)

The assurance of stability of a model, consisting in generation of a correct model in the whole range of functional features as foreseen for a designed product, forms a crucial factor of the process. It is especially difficult for some types of models (e.g. surface models) and requires consistent usage of correct methods of geometrical modeling [13] and testing of the whole spectrum of methods of geometrical modeling as far as model stability is concerned. This knowledge should be captured in this part of knowledge base which deals with CAD tools and it should be consistently used.

3.2. An acquisition tool

It has been decided to use Protégé [15] system for knowledge acquisition. This system is based on structurization and granulites of knowledge, of open character which allows

defining its own ontology of knowledge base system and remote team work within the system.

It is used for designing only knowledge base system as well as acquiring, collecting and managing knowledge base. Therefore, it is used by knowledge engineers, application engineers and domain experts. A big number of applications, which extend possibilities of the system, allow graphical representation of base elements, import and export to various representation forms. The last of the mentioned possibilities is used for creating a system of explanations and justifies operation of Generative Model.

3.3. The process of knowledge acquisition

Knowledge acquisition is realized in Protégé system by means of electronic forms and takes into consideration multi-perspective view on the analyzed domains [10] and personal character of designing knowledge [16] together with work in designing teams. Preparatory phase for knowledge acquisition is done by designing a system of knowledge acquisition in Protégé system, which consists in designing a structure of knowledge base. The structure of knowledge base is represented by classes and the knowledge itself by instants of theses classes. There is a possibility of choosing inner way of knowledge base representation which influences partly the final shape of knowledge base. OWL (Web Ontology Language) [17] has been chosen for the research.

In practice the principle of knowledge acquisition can be presented in the way presented in Figure 3. Knowledge is reproduced from designing examples i.e. designed and previously modeled products in CAD system, and based on that the structure of products is identified by means of Entities forms and designing process are identified by means of Activities forms. Successively, basing on designers knowledge and bibliography, generalization of solutions used in exemplary products and identification of rules and constraints for product structure elements and design process (Rules, Constraints, Illustrations) is carried.

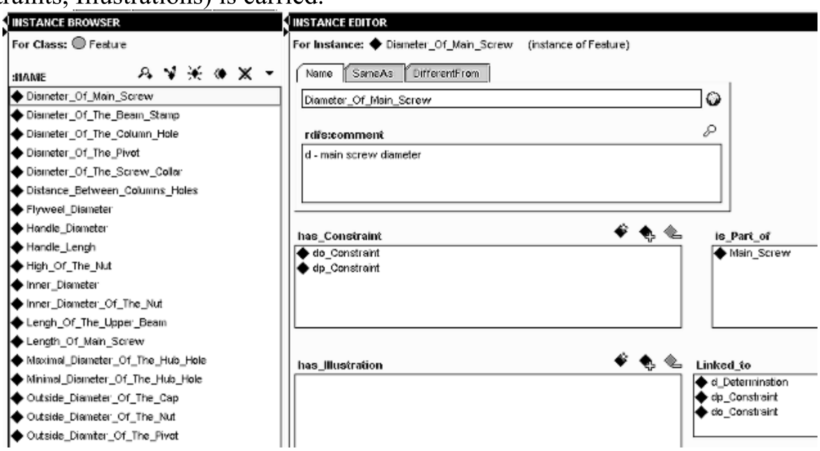

Figure 4. A form for knowledge acquisition for Generative Model –an example

Generalization covers solutions used alternatively and description of their structure, designing processes, rules and constraints. If for example in a designing product a key connection of shaft pin has been used then alternative solutions for this connection are splinted, interference ones, etc. Their identification aims at constructing generative

model on that basis, which for a given class offers the broadest range of possible solutions. Then, for a set input data the most suitable solution can be chosen together with its features.

The very process of knowledge recording consists in filling in previously prepared forms. These forms should not be too complex so that they do not cause expert's feeling of being lost. They divide and separate knowledge granules.

The whole of knowledge base constitutes complex structure where links between particular granules of knowledge base are very important. They create substantial aspect of the captured and structured knowledge.

4. An example of generative model based on the suggested system of knowledge acquisition

The system for knowledge acquisition to Generative Model is constantly developed as far as knowledge base shape is concerned, in details referring to modeling aspects in CATIA environment and the usage of Knowledware tools for models of low stability (surface models of exhaust systems of cars and their elements as well as elements of high speed rotors made of composite materials). As regards solid models many of them have been made according to the suggested methodology, ranging from repeated solutions of general character used in different machinery designs (shafts and their connections, general machinery connections, transmission systems etc.) to devices of common usage and finally tooling for cutting-off dies.

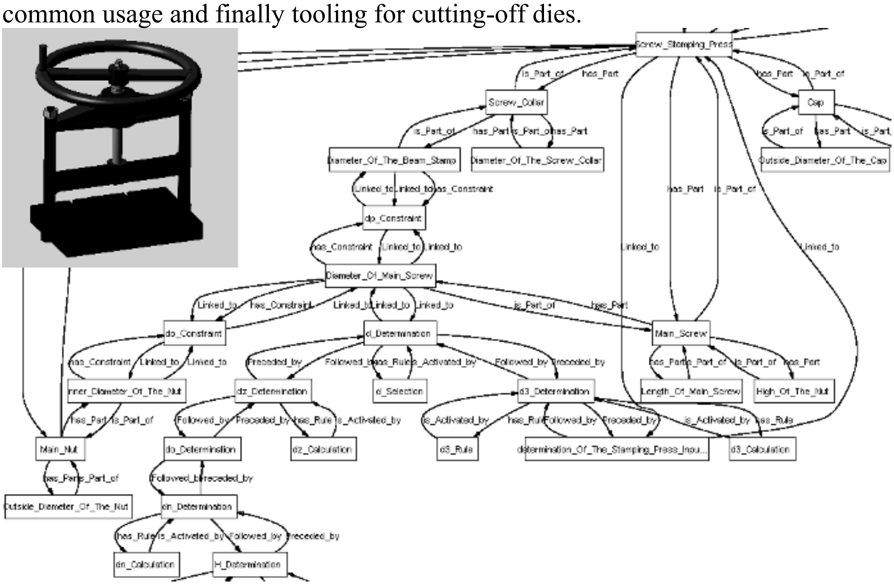

Figure 5. Graphic representation of relations in knowledge base – an example for screw stamping press

5. Conclusions

The presented process of knowledge acquisition forms essential part of methodology of Generative Model construction. For the purpose of knowledge acquisition, forms are

used which are based on ICARE forms from MOKA methodology. The forms differ from ICARE forms since they additionally include a scheme for knowledge acquisition connected with modeling with a given CAD system. Separation of these two parts allows easy system complement with necessary module connected with a given CAD tool. The whole knowledge base together with knowledge acquisition systems have been designed in Protégé system, which uses OWL representation. The research carried on various kinds of designed objects with the use of CATIA system and Knowledgeware tools confirm suitability of the methodology and in particular the system of knowledge acquisition for Generative Model construction for majority of geometrical model types of CATIA system. The models constructed in this way are coherent and stable and they reflect the acquired knowledge. Such a generative model complemented with explanation [7] system generated from knowledge base from Protégé system in CATIA system environment can serve as KBE system successfully.

As refers to Generative model which uses complex surface geometrical models used in designing of some product types in CATIA system, there are instability problems of a model consisting in generation of incorrect shape of designed elements. They result from complexity of the process of surface modeling and from the effects of changes in the model, which are difficult to predict. The problem of stability assurance of generative model using surface models is currently being researched.

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A Knowledge-driven Data Warehouse Model for Analysis Evolution

Cécile FAVRE [1], Fadila BENTAYEB and Omar BOUSSAID
ERIC Laboratory, University of Lyon 2, France

Abstract. A data warehouse is built by collecting data from external sources. Several changes on contents and structures can usually happen on these sources. Therefore, these changes have to be reflected in the data warehouse using schema updating or versioning. However a data warehouse has also to evolve according to new users' analysis needs. In this case, the evolution is rather driven by knowledge than by data. In this paper, we propose a Rule-based Data Warehouse (*R-DW*) model, in which rules enable the integration of users' knowledge in the data warehouse. The *R-DW* model is composed of two parts: one fixed part that contains a fact table related to its first level dimensions, and a second evolving part, defined by means of rules. These rules are used to dynamically create dimension hierarchies, allowing the analysis contexts evolution, according to an automatic and concurrent way. Our proposal provides flexibility to data warehouse's evolution by increasing users' interaction with the decision support system.

Keywords. Data Warehouse, Schema Evolution, Knowledge, Rule

Introduction

The design of integrated concurrent engineering platforms has received much attention, because competing firms strives for shorter design delays and lower costs. Concurrent engineering allows for parallel design, thus leads to shorter design to market delays. It however requires advanced coordination and integration capabilities [4]. Concurrent engineering, also known as simultaneous engineering, is a non-linear product or project design approach during which all phases operate at the same time.

Data warehouse systems must operate in a fully concurrent environment. Materialized views must be maintained within the data warehouse dynamically with the data provided from data sources. Data sources can generate concurrent data updates and schema changes within the data warehouse. However, we think that data warehousing is a technology that is difficult to consider from a concurrent engineering point of view concerning the users' implication in the process. The data warehouse design corresponds to a linear process in which users are indirectly implied. First, a study of the data sources and the users' analysis needs is needed. Second, the model of the data warehouse has to be built. Last the ETL (Extract Transform and Loading) process has to be defined and implemented. End users make analyses entirely driven by the data warehouse model. By considering a concurrent engineering approach for users in the data warehouse, we need to cope evolutions of analysis possibilities defined by users.

[1] Corresponding Author: Cécile Favre, ERIC Laboratory - University of Lyon 2, 5 av. Pierre Mendès-France, 69676 Bron Cedex, France; E-mail: cfavre@eric.univ-lyon2.fr.

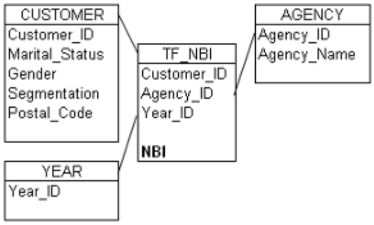

Figure 1. Data warehouse model for the NBI analysis.

It is impossible to take into account the evolution of all users' analysis needs, particularly when these needs are based on their knowledge. Indeed, sometimes users have knowledge which is not represented in the data warehouse but which is likely to be used for an analysis. To enable evolution of data warehouse, the administrator has to centralize the analysis needs and knowledge on which they are based. This process is a difficult task to achieve. Thus, we propose a new data warehouse model based on rules, named *R-DW* (*Rule-based Data Warehouse*), in which rules integrate users' knowledge allowing real time evolution of the analysis possibilities.

Our *R-DW* model is composed of two parts: a "fixed" part, defined extensionally, and an "evolving" part, defined intentionally with rules. The fixed part includes a fact table and dimensions of the first level (dimensions which have a direct link with the fact table). The evolving part includes rules which define new analysis axes based on existing dimensions and on new knowledge. These rules create new granularity levels in dimension hierarchies. Thus this model makes the evolution of analysis needs expressed directly by users easier, without the administrator's intervention.

The remainder of this paper is organized as follows. First, we present a motivating example in Section 1. Section 2 and Section 3 are devoted to the principles of our *R-DW* model and its formal framework. We also present an implementation and a running example with banking data in Section 4. Then we discuss in Section 5 the related work regarding schema evolution and flexibility offered by rule-based languages in data warehouses. We finally conclude this paper and discuss research perspectives in Section 6.

1. Motivating example

To illustrate our approach throughout this paper, we use a case study defined by Le Crédit Lyonnais french bank (LCL[2]). The annual Net Banking Income (NBI) is the profit obtained from the management of customers account. It is a measure that is studied according to dimensions customer (marital status, age...), agency and year (Figure 1).

Let us take the case of the students portfolio manager of LCL. This person knows that a few agencies manage only students accounts. But this knowledge is not visible in the model. It therefore cannot be used to carry out an analysis about student dedicated agencies. This knowledge represents a way to aggregate data, under the form of "if-then" rules, as the following rules which represent the knowledge on the agencies type:

[2]Collaboration with the Management of Rhône-Alpes Auvergne Exploitation of LCL-Le Crédit Lyonnais within the framework of an Industrial Convention of Formation by Research (CIFRE)

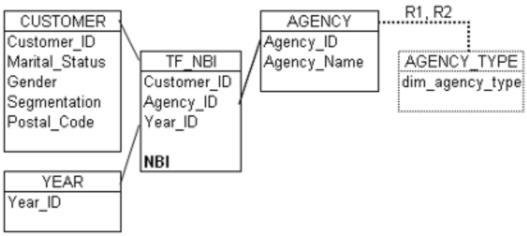

Figure 2. Rule-based Data Warehouse conceptual model for the NBI analysis.

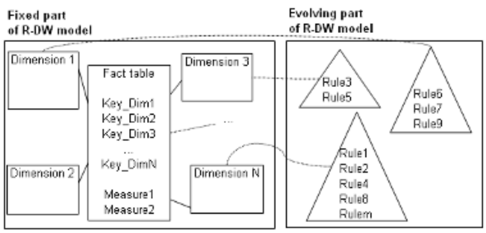

Figure 3. *R-DW* model.

$(R1)$ $if\ Agency\_ID \in$ {'01903','01905','02256'} $then\ dim\_agency\_type =$ 'student'
$(R2)$ $if\ Agency\_ID \notin$ {'01903','01905','02256'} $then\ dim\_agency\_type =$ 'classical'

The objective is then to carry out new analysis based on the user's knowledge. For an example, the objective is to build aggregates, by considering that the facts to aggregate concern a student agency (R1), or a classical agency (R2). Our objective is thus to integrate these rules into the model. Indeed, rules allow us to build the level `AGENCY_TYPE`, by defining the values of the `dim_agency_type` attribute in the dimension hierarchy (Figure 2). To achieve this objective, we propose the *R-DW* model.

2. The R-DW model

The *R-DW* model is composed of two parts: one fixed part, defined extensionally, and one evolving part, defined intentionally with rules (Figure 3). The fixed part can be seen as a star schema because it is composed of a fact table and first level dimensions. The evolving part is composed of rules which generate new granularity levels in dimension hierarchies based on users' knowledge and existing dimensions.

Our model provides to the users a way to express their rules to define dimensions hierarchies. It presents many advantages comparing to existing models by allowing: (1) to dynamically create hierarchies, (2)to make analysis on evolving contexts, (3) to increase the interaction between the user and the information system since the user can integrate his own knowledge.

In the *R-DW* model, rules, namely aggregation rules, are used to create dimension hierarchies by defining the aggregation link between two granularity levels in a dimension hierarchy. These rules are defined by users who express their knowledge. The aggregation rules are "if-then" rules. These rules have the advantage of being very intelligible

for users since they model information explicitly. The then-clause contains the definition of a higher granularity level. The if-clause contains conditions on the lower granularity levels. The following rules define the granularity level AGENCY_TYPE through the dim_agency_type attribute, basing on the AGENCY level (Agency_ID attribute):

$(R1)$ $if\ Agency\_ID \in \{$'01903','01905','02256'$\}$ $then\ dim\_agency\_type\ =$ 'student'

$(R2)$ $if\ Agency\_ID \notin \{$'01903','01905','02256'$\}$ $then\ dim\_agency\_type\ =$ 'classical'

The rules thus make it possible to integrate knowledge to define the various granularity levels of the dimension hierarchies. The advantage in building the dimension hierarchies with rules is that we are able to take into account the users' knowledge in real time. Therefore, the data warehouse model becomes more flexible for analysis. Indeed the users can analyze data according to the new granularity levels defined by their rules.

To take into account the knowledge or the analysis needs of different users simultaneously, we have to deal with "versions" of rules when the users define the same analysis needs by different ways. Let us take the example of age groups definition starting from the ages of the table CUSTOMER. The following classes can be defined by two users:

User 1	User 2
$if\ Age < 60\ then\ dim\_age =$ 'less than 60 years old'	$if\ Age < 18\ then\ dim\_age =$ 'minor'
$if\ Age \geq 60\ then\ dim\_age =$ 'more than 60 years old'	$if\ Age \geq 18\ then\ dim\_age =$ 'major'

3. Formal framework

We represent the Rule-based Data Warehouse model *R-DW* by the following triplet:

$$R\text{-}DW = (\mathcal{F}, \mathcal{E}, \mathcal{U})$$

where $\mathcal{F}$ is the fixed part, $\mathcal{E}$ the evolving part et $\mathcal{U}$ the universe of the data warehouse *R-DW*.

Definition 1. *Universe of the data warehouse*

The *universe of the data warehouse* $\mathcal{U}$ is a set of attributes, such as:

$$\mathcal{U} = \{B_1, \ldots, B_\alpha, \ldots, B_z, C_1, \ldots, C_\beta, \ldots\} = \{B_\alpha, 1 \leq \alpha \leq z\} \cup \{C_\beta, \beta \geq 1\}$$

where $\{B_\alpha, 1 \leq \alpha \leq z\}$ is the set of z predefined attributes (in the fixed part $\mathcal{F}$) and $\{C_\beta, \beta \geq 1\}$ is the set of generated attributes (defined in the evolving part $\mathcal{E}$).

Definition 2. *Fixed part of R-DW*

The *fixed part of R-DW* is represented by:

$$\mathcal{F} =< F, \mathcal{D} >$$

where F is a fact table and $\mathcal{D} = \{D_s, 1 \leq s \leq t\}$ is the set of t first level dimensions which have a direct link with fact table F. We assume that these dimensions are independent.

Example 2. In the Figure 1, $\mathcal{F} =< TF\_NBI, \{AGENCY, YEAR, CUSTOMER\}>$ is the fixed part of the *R-DW* for the NBI analysis.

The expression of new analysis needs induces the definition of new granularity levels in dimension hierarchies.

Definition 3. *Dimension hierarchy and granularity level*

Let $R\text{-}DW = (< F, \mathcal{D} >, \mathcal{E}, \mathcal{U})$ be a data warehouse.

Let $D_s.H_k, k \geq 1$ be a *dimension hierarchy* $D_s \in \mathcal{D}$.

The dimension hierarchy $D_s.H_k$ is composed of a set of w ordered granularity levels noted L_i :

$D_s.H_k = \{L_1, L_2, \ldots, L_i, \ldots, L_w, w \geq 1\}$ where $L_1 \prec L_2 \prec \ldots \prec L_i \prec \ldots \prec L_w$.

The granularity level L_i of the hierarchy H_k of dimension D_s is noted $D_s.H_k.L_i$ or L_i^{sk}. The granularity levels are defined with attributes called generated attributes.

Definition 4. *Generated attribute*

An attribute $C_\beta \in \mathcal{U}, \beta \geq 1$, is called *generated attribute*.

C_β characterizes a granularity level in a dimension hierarchy. To simplify, we suppose that each granularity level of dimension hierarchy is represented by only one generated attribute, even if it is possible to generate more than one attribute per level.

Thus, the generated attribute C_β which characterized the granularity level L_i of hierarchy H_k of dimension D_s is noted $L_i^{sk}.A$. The values of these generated attributes are defined by using the evolving part of *R-DW*.

Definition 5. *Evolving part of R-DW*

The *evolving part of R-DW* is represented by

$$\mathcal{E} = \{< \mathcal{R}_{i.}, L_i^{sk}.A >\}$$

where $\mathcal{R}_{i.} = \{r_{ij}, 1 \leq i \leq w, 1 \leq j \leq v\}$ is a set of v aggregation rules defining the values of the generated attribute $L_i^{sk}.A$. $\mathcal{E}$ represents the set of w granularity levels of hierarchy H_k of dimension D_s and their associated rules.

Definition 6. *Aggregation rule*

An *aggregation rule* defines the aggregation link which exists between two granularity levels in a dimension hierarchy. It is based on a set $\mathcal{T}$ of n rule terms noted RT_p, such as:

$$\mathcal{T} = \{RT_p, 1 \leq p \leq n\} = \{U \ op \ \{set|val\}\}$$

where U is an attribute of the universe $\mathcal{U}$; *op* is a relational operator ($=, <, >, \leq, \geq, \neq$, ...), or an ensemblist operator ($\in$, $\notin$, ...) ; set is a set of values and val is a given value.

Example 6a. $RT_1 : Agency\_ID \in \{$'01903','01905','02256'$\}$
$RT_2 : Year\_ID < 2001$
$RT_3 : Gender =$ 'F'

An aggregation rule is an "*if-then*" rule. The conclusion of the rule ("then" clause) defines the value of the generated attribute. The premise of the rule ("if" clause) is based on a composition of conjonctions or disjonctions of these rule terms:

$$r_{ij} \ : \ if \ RT_1 \ (and|or) \ RT_2 \ ... \ (and|or) \ RT_n \ then \ L_i^{sk}.A = val$$

Example 6b. The following rules define the values of the attribute `dim_type_agency` which characterizes the granularity level `AGENCY_TYPE`:

$(R1)$ $if \ Agency\_ID \in \{$'01903','01905','02256'$\}$ $then \ dim\_agency\_type =$ 'student'
$(R2)$ $if \ Agency\_ID \notin \{$'01903','01905','02256'$\}$ $then \ dim\_agency\_type =$ 'classical'

Example 6c. The following rule defines the value `'married women'` of the attribute `dim_persons_group` according to attributes `Marital_Status` and `Gender` of `CUSTOMER` table:

$if \ Marital\_Status =$ 'Married' $and \ Gender =$ 'F' $then \ dim\_persons\_group =$ 'married women'

dim_agency_type
- if Agency_ID∈{'01903','01905','02256'} then dim_agency_type='student'
- if Agency_ID∉{'01903','01905','02256'} then dim_agency_type='classical'

dim_age
- if Age < 60 then dim_age='less than 60 years old'
- if Age ≥ 60 then dim_age='more than 60 years old'

dim_persons_group
- if Gender='F' and Marital_Status='Married' then dim_persons_group='married women'
- if Gender='F' and Marital_Status≠'Married' then dim_persons_group='not married women'
- if Gender='M' and Marital_Status='Married' then dim_persons_group='married men'
- if Gender='M' and Marital_Status≠'Married' then dim_persons_group='not married men'

Figure 4. Evolving part of the *R-DW* data warehouse for the NBI analysis.

Thus aggregation rules create or enrich a dimension hierarchy by defining the values of the generated attribute according to a condition (Example 6b.) or a composition of conditions (Example 6c.). These rules translate the knowledge provided by users.

4. Case study

To validate our approach, we implemented a prototype of our *R-DW* model taking into account knowledge provided by a user. We developed a Web platform (HTML/PHP) behind Oracle DBMS used to store the fact table and dimension tables. One additional table contains the aggregation rules. The Web platform allows the user to define and visualize the rules that generate the analysis axes. It also allows the visualization of the query results. We applied our model on banking data for the NBI analysis. The fixed part of the model is represented in the Figure 1. Different dimension hierarchies are represented by the evolving part of the *R-DW* model in the Figure 4. Thus, the user will be able to run NBI analyses, not only by considering dimensions of the first level, but also by considering new granularity levels like agency type, age class...

In our first prototype, we have implemented the computation of aggregates for the analysis on the fly. We initially restricted ourselves to a decisionnal query with an aggregation according to one granularity level of a dimension hierarchy. This aggregation takes the form of a PL/SQL stored procedure of the DBMS. This procedure builds an aggregates table, by creating the SQL queries needed, according to the algorithm of the Figure 5. This algorithm can be used to answer the query "What is the NBI average for the different types of agency?". The agency type is determined by two rules. Thus, the aggregates table contains two tuples corresponding to the NBI average for students and classical agencies. These values are obtained with the following SQL queries:

NBI average for student agencies:	*NBI average for classical agencies:*
SELECT MOY(NBI) FROM TF_NBI, AGENCY WHERE TF_NBI.Agency_ID=AGENCY.Agency_ID AND Agency_ID IN ('01903','01905','02256');	SELECT MOY(NBI) FROM TF_NBI, AGENCY WHERE TF_NBI.Agency_ID=AGENCY.Agency_ID AND Agency_ID NOT IN ('01903','01905','02256');

To obtain NBI average for student (resp. classical) agencies, in the WHERE clause of the query is the premise of the rule which defines a student (resp. classical) agency.

5. Related Work

A schema evolution is needed to take into account new analysis needs. According to the literature, schema evolution can be performed following two different ways, namely

```
Algorithm
Notation: The premise of the rule is written body(r_ij), and its conclu-
sion is written head(r_ij).
Input:  fact table F, set of aggregation rules R, attribute A, mea-
sure F.M_q, aggregation operator op,
Output: aggregates table TAgreg
Begin
    For each r_ij ∈ R
       If A ∈ head(r_ij) Then
          TAgreg =' SELECT op(F.M_q) FROM F WHERE body(r_ij)'
       End if
    End for
End
```

Figure 5. Aggregates computation algorithm.

schema updating and schema versioning. Schema updating consists in transforming data from an old schema into a new one [2,8]. In this case, only one schema is supported. On the contrary, schema versioning consists in keeping track of all versions of a schema [3,10]. In [1], the authors use versions too. They distinguish real version from alternative version. Alternative versions are used for simulating scenarios. They are derived by the data warehouse administrator from a previous version. Our *R-DW* model allows simulations too, but driven by users. Schema updating and versioning constitute a solution to the dimensions evolution, when the latter is induced by the evolution of the data themselves. However, once the data warehouse created, the users can only carry out analysis provided by the model. Thus they do not provide a solution to take into account new analysis needs which are driven by the expression of users' knowledge.

In spite of their disadvantages, these two approaches bring a certain temporal flexibility to the data warehouse model. Other works aimed at bringing flexibility within the data warehouse use mostly rule-based languages. Firstly, concerning data warehouse schema definition flexibility, two approaches are possible: using rules either to express the analysis needs [9] or the knowledge about data warehouse construction [11]. These different works propose to automatically generate the data warehouse schema from source schemas using rules but the schema's evolution is not taken into account. Create a new data warehouse when an analysis need appears is not a solution, even if this creation is automated. Secondly, the administrator must define some integrity constraints to ensure the consistency of not only the data, but also the analysis. In [5,7], the expressed integrity constraints use the data semantic to manage data inconsistency within the analysis. However the data semantic is not exploited for the analysis. The proposed approaches allow consistent analyses but their evolution is not evoked. Thirdly, in order to make the analysis more flexible, a rule-based language has been developed in [6] to manage exceptions during the aggregation process. This language allows to intentionally express redefinitions of aggregation hierarchies. We think that it is possible to treat these exceptions with the *R-DW* model.

Rule-based languages allow flexibility within data warehouses in different ways. It is precisely this flexibility which we seek for the analysis evolution. This evolution is conditioned by that of dimensions. The data warehouse schema updating or versioning constitute answers to the problem of dimensions evolution, when this latter is oriented by the evolution of data themselves. Moreover, the intervention of the administrator is

needed to implement these solutions. With the *R-DW* model, we bring a solution to take into account the emergence of new analysis needs directed by the expression of users' knowledge, without the administrator intervention, thus in a concurrent way.

6. Conclusion

In this paper, we proposed a new data warehouse model based on rules (*R-DW*), where rules allow us to introduce users' knowledge for analysis purposes. Our *R-DW* model is composed of two parts: one fixed part, which contains a fact table and first level dimensions and one evolving part, defined with rules, which generate granularity levels of dimension hierarchies. Thus the dimension hierarchies are generated according to users's knowledge therefore satisfying their analytical needs. The *R-DW* model presents the advantage of being able to dynamically create dimension hierarchies, without the administrator's intervention, in a concurrent way. We proposed a prototype of our *R-DW* model and applied it on the LCL banking data case study.

The perspectives opened by this study are numerous. First, we have to extend the analysis possibilities of our implementation. Then we intend to measure the performance of our approach in terms of storage space and response time. Furthermore we plan to define constraints on rules and a language that allows us to validate these rules. Moreover, in this paper, we presented an approach that involves the users in the analysis process by allowing them to integrate their knowledge in the system. We think it would be interesting to discovery new rules using non supervised learning methods.

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An approach for building Project Memories to facilitate design process in a concurrent engineering context

Davy MONTICOLO[a,b], Vincent HILAIRE[a], Abder KOUKAM[a], Sébastien MEUNIER[b]
[a]*SeT laboratory, UTBM 90010 Belfort Cedex FRANCE*
[b]*Zurfluh-Feller 25150 Roide FRANCE*

Abstract. This article presents a project memory architecture and an approach to build it. This is a result of the analysis and follow-up of product development projects in a company of four hundred employees. The development of a product is a multi-field project where engineers with different specialities collaborate to achieve the same goal. These professional actors carry out tasks related from the stages defined by product development lifecycle. Each stage requires the contribution of know-how and knowledge in order to achieve the laid down goals. Our approach consists in studying each stage of the process of engineering and defining knowledge necessary to capitalize in order to organize the project memory. Afterwards, the development of such knowledge base will be used to help professional actors to accomplish their task in bringing knowledge of past projects

Keywords. Project Memory, Concurrent engineering, Knowledge engineering

Introduction

In today's challenging global market, companies have to innovate in order to improve competitiveness and business performance. They must bring innovative products to market more effectively and more quickly to maximize customer interest and sales. The pressures to reduce time, improve product quality, and lower costs have not gone away; they are being reaffirmed and folded into programs that focus on delivering the "right" product. Product leadership companies must continue to enter new markets with innovative products. This requires leveraging and reusing the product-related intellectual capital created by partners working together. Business innovation must occur in several dimensions: project organization, product definition, production engineering, ergonomics design, environmental impacts, etc.
In order to synthesize all this knowledge we propose to use the project memory concept. The project memory is a memory of knowledge and information acquired and produced during the realization of the projects [17]. Thus, project memories constitute a basis for knowledge capitalization and reuse [3] [20].
The issues addressed in this paper are: first how to define a project memory architecture adapted to concurrent engineering, second how to build project memories during the product development lifecycle.

Concurrent engineering supports a strategic business approach with a consistent set of methodologies and software solutions for promoting the collaborative creation, management, distribution and proper use of product. We have chosen to base our approach on a product development lifecyle. Indeed, engineering methodologies as well as the products development lifecycle constitute the base of the project memory architecture and support the development of knowledge elements which will compose the project memory. Moreover, the application of a product development lifecycle provides a first guarantee on the reliability of generated information. The lifecycle is composed of phases. Each phase is described by stages to follow with the professional actors responsibilities. For each stage the tasks to be realized are detailed as well as the deliverable documents, numerical models, concepts... In order to analyse the design activity progress, we represent each stage with the IDEF0 formalism [1]. Moreover for each stage we identify the exchanges and collaboration by using interaction diagrams with the formal tool RIO [11]. These two models allow us to characterize and to classify the knowledge elements necessary for the project memory architecture. Moreover this approach eases the project memory build process by positioning the capitalized knowledge elements related by product development stages.

1. Project memories in concurrent engineering context

1.1. Industrial context

Our works are deployed in a company of four hundred employees in the domain activity of window rolling shutters. The research and development department is constituted by fifty technicians. The method department, laboratory department and the design and engineering department work together through a project organization in a concurrent engineering concept.

One of the problems is that professional actors are enabled to reuse their collaborative professional experience from past projects. Thus the direction of the company has decided to develop a knowledge engineering approach to resolve this problem.

1.2. Why to build project memories

The company is a unit production of knowledge [10]. Indeed in a model of concurrent engineering, projects use different professional specialities to design and develop products. Each professional actor with his specialities brings several competences to resolve specifically tasks. Those competences use knowledge to realise activities. Knowledge engineering approaches model this type of knowledge to implement methods and classification technique to make this knowledge accessible in a form defined according to the context [6][3].

In an engineering context, it's difficult for professional actors to have an overview of a project or to remember the collaborative work of past projects. Only the teams which have the practice to work together and a maturity experience, can define the fundamental knowledge to store.

Thus we have chosen to store this knowledge in the form of project memory. The project memory contains knowledge acquired and produced during the realization of the projects [18]. In an organisation of project and in a concurrent engineering context, project memories seem to be a good solution to capitalize knowledge. Project

memories save the progress of the project activities from which we will be able to structure the types of knowledge to be filed.

2. Activity Modelling and cartography of knowledge

In company the projects carried out within the context of concurrent engineering follow a product development lifecycle [8]. This lifecycle allows to describe the phases of the project. Each phase is composed by several stages. In the lifecycle center we have a multi-field team. Indeed each phase requires professional actors of different specialities and each stage can be carried out simultaneously as it shown with Gomes's lifecycle (Figure 1).

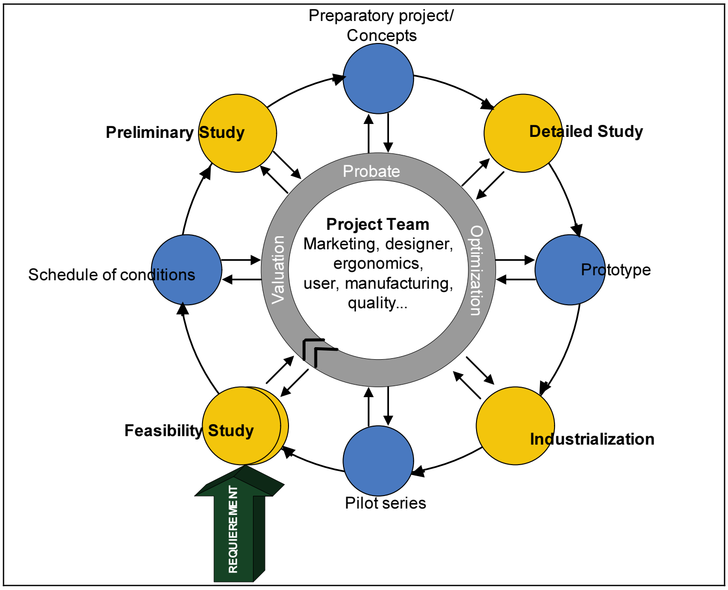

Figure 1. Cycle illustrating concurrent engineering [9]

The analysis of the activities on several projects in the company allows us to validate the product development lifecycle with the four phases: feasibility study, preliminary study (called in the company pre study), detailed study (named study) and industrialization. Each phase is structured according to some recurring usual stages for all projects. Those stages can be processed simultaneously or sequentially if the stage is a stake.

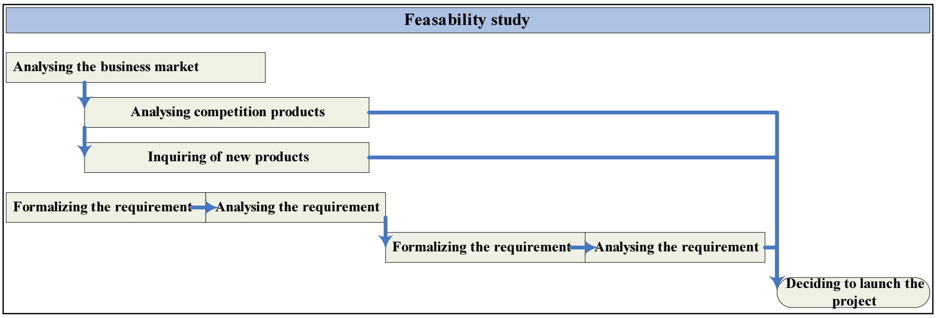

Figure 2. Stages of the preliminary study phase

The figure 2 presents the scenario of the *feasibility study* stage for a past project. We observe two sequential stages: *Formalizing the requirement* and *analysing the requirement.* In this project these two stages were repeated. The other stages are simultaneous; the team project works in a concurrent engineering context. The last stage *deciding to launch the project* represents the phase stake.

In order to model the progress of each stage we use IDEF0 diagrams [2]. This formalism enables us to represent the sequence of the Project. The figure 3 shows the progress of the feasibility study phase with four stages from *Market Analysis* to *Deciding to launch the project.* We observe the '*analysing the requirement'* stage can result in taking bake the '*Formalizing the requirement stage'.* Moreover we can represent actors implication by their initial (DM and LS for the Market analysis stage), elements necessary for each stage (Product and Market Informations for the first stage, elements result for each stage (Perception of a requirement). Additionally, we notice the '*deciding to launch the project'* stage depend on the control element '*marketing strategy of the company'* to be realised.

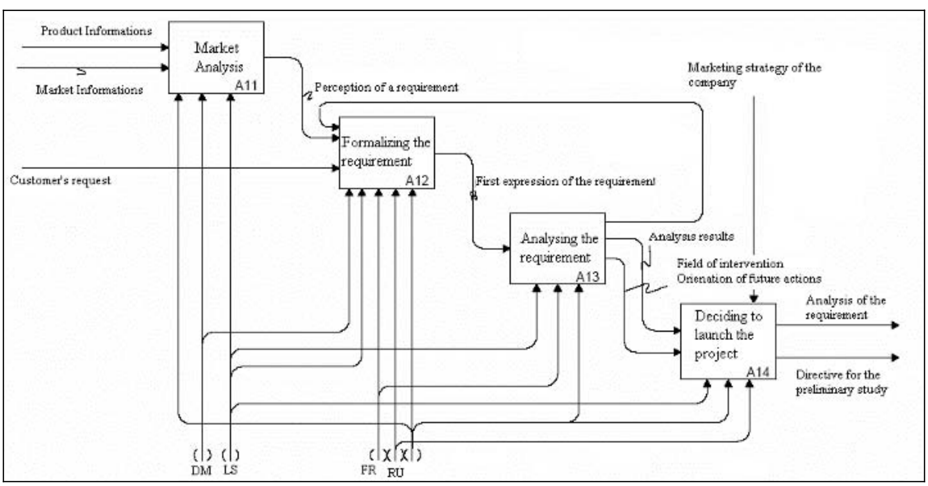

Figure 3. IDEF0 diagram for feasibility study phase

In order to obtain an exhaustive modeling of the activity of engineering, we supplement diagrams IDEF0 by the formalism RIO [11]. It is based on three concepts: roles, interactions and organizations. The roles are abstractions of behaviors. Those behaviors can mutually act one on the other according to the interaction model. Such a model which groups generic behaviors and their interactions constitutes an organization. Thus the organization is a description of coordination structures. Coordination occurs between the roles as interactions take place.

At the time of the activity modeling we consider a stage of the product development lifecycle as a RIO organization. For each stage, we define several roles according to the professional actors enumerated by diagrams IDEF0. We attribute to those the competences they use to tackle the stage. Each competence is described with a series of knowledge. The interaction between those roles highlights two types of results; the exchanges between the roles and the emergence of collective competence. Thus, to achieve a task, a role uses one or more competences which require one or more knowledge. A role interacts with other roles to achieve a task and thus develop one or more collective competences. In the stage *decision to launch the project* in the feasibility study phase, we find five roles (Figure 4). The role 'Commercial' uses two of its competences for this stage: *To define the strategy for each customer* and *to know the functional needs for the customers.*

The first competence requires the knowledge of the *Overall marketing strategy of the company* as well as the knowledge of the *Marketing strategy of the company towards the customer*. The interaction among the five roles to this stage produces two results: the agreement for the launching of the project and the directives for the preliminary study. Moreover, this cooperative work allows to develop or to enrich collective competence *to perceive the feasibility and the profitability of the project*.

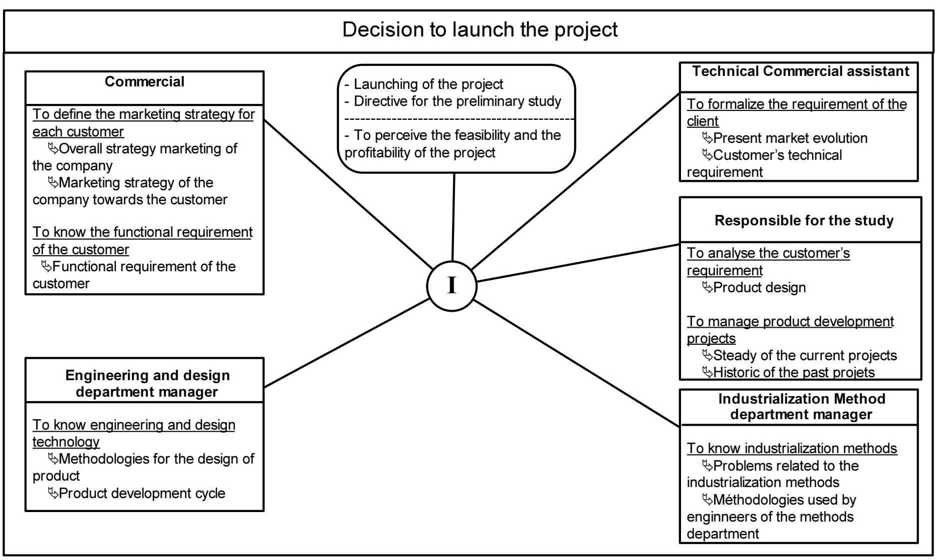

Figure 4. RIO model for the stage 'decision to launch the project'

3. Types of knowledge to be capitalized

The activity modelling using IDEF0 diagrams and the RIO formalism allows us to determine two types of knowledge; **Knowledge related to the professional competences** and **knowledge described the project progress.** The first one held by the roles and played by the professional actors as shown in Figure 5.

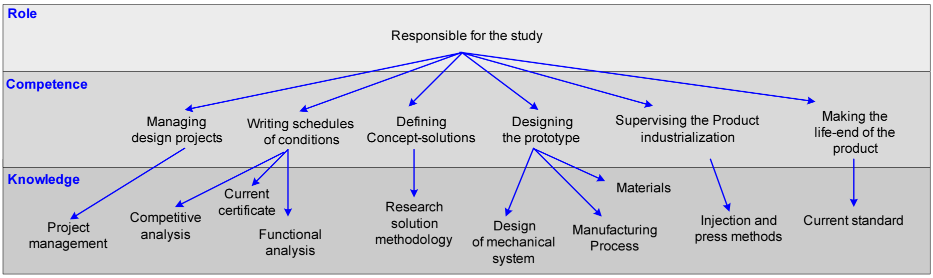

Figure 5. Tree presenting Role\Competence\Knowledge

Thus for each role we can build a tree ‘Roles\Competences\Knowledge’. This tree highlights competences useful to a role during a project as well as knowledge necessary to the realization of the activities of engineering. Consequently this knowledge related to professional competences must be capitalized. Moreover it is imperative to position them in a system of reference. In concurrent engineering, the cycle of development of products describes the process used by the professional actors to design, develop and industrialize a product. The cycle of development of products is consequently a system of reference since it enables us to position each emerging knowledge inside a phase or from a precise stage of the project.

4. Architecture of the Project Memory

4.1. Knowledge related to the project progress

The product development lifecycle has the same phases (feasibility study, preliminary study, detailed study and industrialization) for each project. On the other hand the stages and sub stages inside the phases can be different and be treated in various orders. The professional actors and particularly the project leader define the sequence of the stages for each phase. This sequence must be capitalized, it presents the project progress and defines a system of reference to position the professional knowledge.
To introduce the project progress into the project memory we present the project context i.e. its origins, its organization, its objectives, its participants... Therefore for knowledge related to the project progress we obtain two aggregates of knowledge (Figure 6): The ***project context*** and the ***project evolution***. The project context brings all the knowledge characterizing the project gathered in three titles: *Objectives*, *Environment* and *Organization*. The ***project evolution*** makes it possible to describe all the project stages. This knowledge aggregate defines the system of reference for the knowledge capitalization.

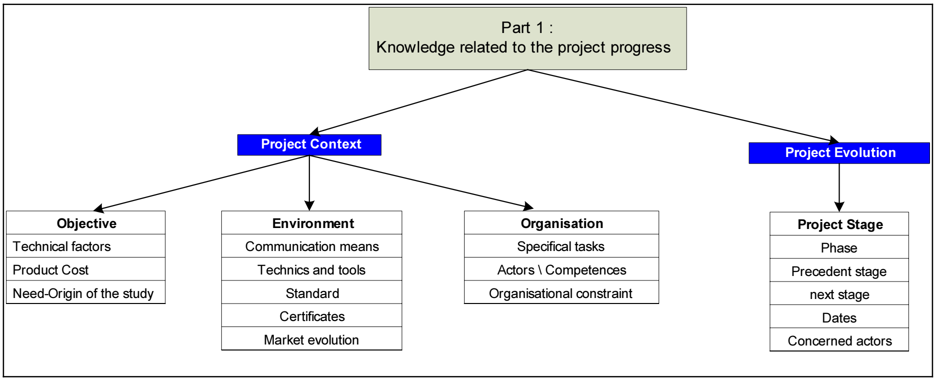

Figure 6. Knowledge related of the project progress

4.2. Knowledge related with professional competences

The competence is defined initially at the individual level: "it is the capacity for an individual to implement his knowledge and to develop its know-how within a professional framework" [15]. In addition the collective competence is made by interaction with professional actors working together in the same service and in the same project team for a common realization [13] [21].
In order to capitalize knowledge we use the model Knova-Sygma [19]. This model presents a knowledge capitalization centred on human professional competences. We enrich this model by adding the element of knowledge ***professional experience*** composed of three types: successes, difficulties and failures (Figure 7).

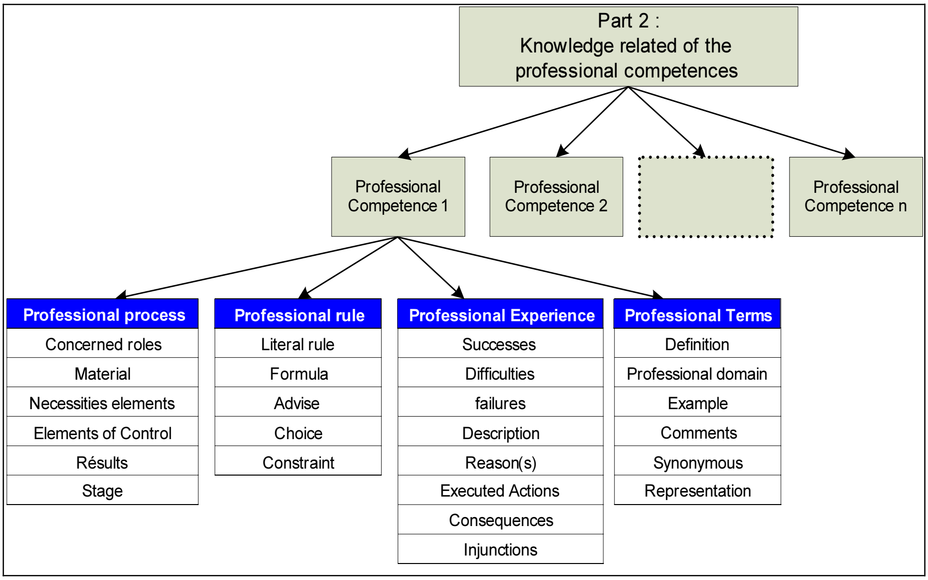

Figure 7. Knowledge related of the professional competences

5. Results and possibilities

At present, knowledge of five finished projects is stored in project memories. Our first reports of the use of the memories projects allows us to draw up a table of some examples of use case (Figure 8).

Project Memory use case	Knowledge element consulted
To research the meaning and the representation of a technical element	Professional Terms
In the case of routine design [12], to find design parameters of a product element	Professional rules for the professional competence 'designing the product elements'
To reuse wrapping models for new pieces	Professional rules for the professional competence 'developing and optimising the wrapping'
To research solutions for quality problems	Professional experience for the professional competence : « injecting a plastic piece »
To anticipate the study planning	Project evolution
To choose a new project team	Project context
To define a new industrialization process	Professional process for the professional competence « industrializing the product elements »

Figure 8. Example of Project Memory use cases

A test of project memory redaction by the professional actors shows us this work is long, difficult and provides uncorrect results. Indeed the information capitalized was mainly related to the professional actor's point of view and only an collaborative approval work attests the reliability of the capitalized knowledge.
In order to assist the professional actors we wish to develop an information processing system coupled to a collaborative PLM (Product Life Management) framework or groupware. This knowledge engineering tool will be based on distributed artificial intelligence technologies. It will assist professional actors to build project memories by organizing and structuring the information placed in the groupware during projects.

6. Conclusion

In a concurrent engineering context, professional actors carry out projects for the development of new products. At the time of those projects, a multitude of knowledge is created. Many approaches exist to structure this knowledge. Among those we note design rationale methods such as QOC [16], IBIS [7], DRCS [14], DYPDKM [4] and DRAMA [5]. These methods structure knowledge for the resolution of problem in order to improve the decision-making. Our model of project memory is designed from the needs defined by the roles acted by the professional actors. At the time of the realization of a task, a professional actor acts a specifically role and the project memory brings knowledge capitalized (for the same role) from similar stages carried out in other projects. Thus in this organisation the design rationale is contained by knowledge elements related to professional competences more especially from 'professional process' and 'professional rules'.
Therefore we have defined a model of project memory based on two types of knowledge; *knowledge related to the project progress* and *knowledge related to the professional competences*. We plan to develop a knowledge engineering module coupled to a collaborative platform with the PLM concept in order to assist professional actors to build project memories.

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Decomposition-based Reasoning for Large Knowledge Bases in Description Logics

Thi Anh Le PHAM [a,1] and Nhan LE-THANH [b]

[a] *Laboratoire I3S, Université de Nice Sophia-Antipolis, France*

[b] *Laboratoire I3S, Université de Nice Sophia-Antipolis, France; E-mail: Nhan.Le-Thanh@unice.fr*

Abstract. Reasoning in a Knowledge Base (KB) is one of the most important applications of Description Logic (DL) reasoners. The execution time and storage space requirements are both significant factors that directly influence the performance of a reasoning algorithm. In this paper, we investigate a new technique for optimizing DL reasoning with the purpose to minimize two factors above as much as possible. This technique is applied to speed-up TBox and ABox reasoning, especially for large TBoxes. The incorporation of this technique with previous optimization techniques in current DL systems can effectively solve intractable inferences. Our technique is called "ontology decomposing" in which decomposition of one ontology to many sub-ontologies is implemented such that it still preserves the semantic and inference services of original ontology. We are concerned about how to reason effectively with multiple KBs and how to improve the efficiency of reasoning over component ontologies.

Keywords. Optimization, distributed description logics, reasoning, ontology decomposing.

Introduction

For the large TBoxes, effective reasoning is a big challenge because of intractable inferences. A major cause is happened by General Concept Inclusions (GCIs). Each GCI causes a disjunctive expression that is added to the label of every node in the tree generated by the tableaux algorithm and this leads to an exponential increase in the size of the search space to be explored by the $\sqcup$-rule. Consequently, a reduced number of GCIs can considerably degrade the performance of a DL reasoner. Therefore obvious optimization techniques for reasoning focus often on reducing most GCIs from a terminology. Our technique, parallelizing tableaux algorithms, is not beyond of this purpose. Instead of reasoning on a given ontology, the tableaux algorithms are concurrently implemented on many sub-ontologies, that are generated from original ontology. As a result, we introduce the decomposition of an ontology into several such sub-ontologies in the same domain of the first ontology. Our technique is called "overlap decomposing" in which decomposed ontologies (called sub-ontologies) are kept all of primitive concepts, primitive roles and defined concepts of the original ontology, only the set of axioms are divided into several sets of axioms. Hence, the number of axioms is reduced significantly. In this paper, the algorithm for decomposing is not presented. We only focus on the most important properties of decomposed ontologies, they consist of the syntactic, semantic and inferences preservation of original ontology. The reasoning in the system of decomposed ontologies is implemented with two methods, the one is called "distributed" method, in which decomposed ontologies are represented in a distributed system by distributed description logic (DDL) and a distributed tableau algorithm are applied. The other, is called "parallel" method, reasoning algorithm for this method is the normal tableau algorithm. The algorithms are designed so that reasoning results within decomposed ontologies are the same with reasoning in original ontology.

The paper is organized as follows. Section 1 discusses some related works, we recall several optimization techniques that are applied in current DL reasoning systems and we list some definitions in DDL. Section 2 defines an overlap decomposing of a TBox and provides a distributed TBox with its properties. In sections 3 and 4, we present the algorithms for parallel reasoning and distributed reasoning in DDL, and we also briefly prove the soundness and completeness of the reasoning algorithm in DDL.

[1]Corresponding Author: Laboratoire I3S, UMR 6070, CNRS Université de Nice Sophia-Antipolis, France; E-mail: tpham@i3s.unice.fr.

1. Related works

1.1. Optimization Techniques

The study of previous optimization techniques for solving the reasoning problems in Description Logics aims eliminating "redundant" non-deterministic, minimizing applications of expansion rules during satisfiability checking (see, e.g., [2]). In this section, we brief only recall some optimizing techniques that relate to our solution.

1.1.1. Normalization, simplification and encoding

In general terminologies, large and complex concepts are usually built up from the less complex descriptions. Whenever checking the satisfiability of a concept expression by the basic tableaux algorithm, one implement unfolding these large and complex concepts, a clash is only detected when an atomic concept and its negation occur in the same node label. It is not effective in the case that a clash can be detected immediately due to obvious unsatisfiability in its description.

Example 1: testing the satisfiability of the concept expression $\exists$ R.C $\sqcap\forall$ R.$\neg(C \sqcup D)$.
If C is large then the unfolding of C can lead to costly wasted work, while if $\exists R.C \sqcap \forall R.\neg(C \sqcup D)$ is transformed into $\sqcap\{\neg(\forall R.\neg C), \forall R.\neg \sqcap \{C, D\}\}$, then a contradiction will be detected immediately, independently with the structure of C. Hence, the detection of clashes can be addressed by normalizing and recoding all concept expressions into a lexically normalized form, and by identifying lexically equivalent expressions. These transformations are realized by the normalized and encode functions in [2]. Simplifications can be also examined during the normalizing process for eliminating redundancy and help to identify obvious satisfiability and unsatisfiability. Contradictions would be detected whenever a concept expression and its negation appear in the same node label.

1.1.2. GCI absorption

This technique aims to reduce the number of GCIs by absorbing them into primitive concept introduction axioms whenever possible. The structure of absorbable GCIs is suggested by the syntax of Grail concept description language in the Galen terminology that belongs to one of the following forms:
- GCI whose antecedent is only a primitive concept name.
- GCI whose antecedent is either a conjunctive concept expression or a non-primitive concept name whose definition is a conjunctive concept expression. Where, the first conjunct of a conjunctive concept expression is always either a primitive concept name or a non-primitive concept name whose definition is a conjunctive concept expression.

Example 2: $CN \sqcap C \sqsubseteq D \Longleftrightarrow CN \sqsubseteq D \sqcup \neg C$

1.1.3. Semantic branching

Syntactic branching in standard tableaux algorithms works by choosing an unexpanded disjunction and searching the different models obtained by adding each of the disjuncts. These branches are not disjoint, so an unsatisfiable disjunct may occurs in different branches, it would lead to waste cost for discovering the unsatisfiability. This problem is dealt with semantic branching technique adapted from the Davis-Putnam-Logemann-Loveland procedure (DPL). For example, tableau expansion of a node x, where $\{(C \sqcup D_1), (C \sqcup D_2)\} \subseteq L(x)$, and C is an unsatisfiable concept expression. Syntactic branching will generate four branches in which have two branches contains C, it is obviously "redundant". By choosing only a single disjunct C and adding $\neg C$ to $L(x)$, one obtain two possible sub-trees for searching in semantic branching technique.

1.1.4. Heuristic

For reasoning algorithms, the heuristic can be employed to attempt searching a good order for inference rule applications (rules heuristics) and, for non-deterministic rules, the order in which explore the different expansion chooses by rule applications (expansion-order heuristics). The goal is trying to select an order that lead earlier to a model discovery (the input will be satisfiable) or to a proof no model exists (The input will be unsatisfiable). One of the most well-known and widely heuristics in SAT problem is MOMS (Maximum Occurrences in clause of Minimum Size) [9]. It is simple, easy to apply, rather precise, and problem-independent. Its goal in DL reasoning is simply to prefer the expressions having maximum occurrences of a disjunct in the disjunctions of the size minimum.

1.2. Distributed Description Logics

Distributed Description Logics (DDL) is proposed by Borgida and Serafini [7] for representing and reasoning about knowledge bases in distributed environments. We briefly recall some definitions of DDL as given in [7].

1.2.1. Syntax

Let $\{\mathcal{DL}_i\}_{i\in I}$, be a collection of description logics, where I is a non empty set of indexes. For each $i \in I$, a TBox $\mathcal{T}_i$ is presented in a particular $\mathcal{DL}_i$. In order to distinguish descriptions in each TBox $\mathcal{T}_i$, we prefix the descriptions with the index of their TBoxes. For example, $i : C$ denotes a concept C of $\{\mathcal{DL}_i\}_{i\in I}$. The semantic mappings between different TBoxes are depicted by using bridge rules.

Definition 1 *(bridge rule) A bridge rule from $\mathcal{T}_i$ to $\mathcal{T}_j$ is an expression of the following three forms :*

(1) $i\ :\ x\ \underset{\longrightarrow}{\sqsubseteq}\ j : y$, into-bridge rule
(2) $i\ :\ x\ \underset{\longrightarrow}{\sqsupseteq}\ j : y$, onto-bridge rule
(3) $i\ :\ x\ \underset{\longrightarrow}{\equiv}\ j : x$, identity-bridge rule.
Where x and y are either two concepts or two roles, or two individuals of $\mathcal{DL}_i$ and $\mathcal{DL}_j$ respectively. The bridge rules from $\mathcal{T}_i$ to $\mathcal{T}_j$ represent the relations between $\mathcal{T}_i$ and $\mathcal{T}_j$ from the j-th TBox point of view. In particular, the into-bridge rule $i\ :\ A\ \underset{\longrightarrow}{\sqsubseteq}\ j : G$ expresses that, from the point of view of $\mathcal{T}_j$, the concept A in $\mathcal{T}_i$ is less general than its local concept G.

Definition 2 *(distributed TBox) A distributed TBox (DTB) $\mathfrak{T} = (\{\mathcal{T}_i\}_{i\in I}, \mathcal{B})$ consists of a collection of TBoxes $\{\mathcal{T}_i\}_{i\in I}$ and a collection of bridge rules $\mathcal{B} = \{\mathcal{B}_{ij}\}_{i\neq j\in I}$ between them.*

1.2.2. Semantics

Each TBox $\mathcal{T}_i$ is interpreted by a local interpretation $\mathcal{I}_i$ in its local domain. Bridge rules are interpreted by using domain relation r_{ij} between domains.

Definition 3 *(Domain Relation) A domain relation r_{ij} from $\Delta^{\mathcal{I}_i}$ to $\Delta^{\mathcal{I}_j}$ is a subset of $\Delta^{\mathcal{I}_i} * \Delta^{\mathcal{I}_j}$. We denote: $r_{ij}(d) = \{d' \in \Delta^{\mathcal{I}_j} | (d, d') \in r_{ij}\}$; $r_{ij}(D) = \cup_{d\in D} r_{ij}(d)$, and $r_{ij}(R) = \cup_{(d,d')\in R} r_{ij}(d) * r_{ij}(d')$, with $D \subseteq \Delta^{\mathcal{I}_i}$ and $R \subseteq \Delta^{\mathcal{I}_i} * \Delta^{\mathcal{I}_j}$.*

The domain relation represents the possibility of mapping individuals from $\Delta^{\mathcal{I}_i}$ to $\Delta^{\mathcal{I}_j}$ from the point of view of $\mathcal{DL}_j$.

Definition 4 *(distributed Interpretation) A distributed interpretation $\mathfrak{J} = (\{\mathcal{I}_i\}_{i\in I}, \{r_{ij}\}_{i\neq j\in I})$ of a DTB combines the local interpretations $\mathcal{I}_i$ of each $\mathcal{T}_i$ on the local domain $\Delta^{\mathcal{I}_i}$ and a family of relations $r_{ij} \subseteq \Delta^{\mathcal{I}_i} * \Delta^{\mathcal{I}_j}$ between local domains.*

A distributed interpretation $\mathfrak{J} = (\{\mathcal{I}_i\}_{i\in I}, \{r_{ij}\}_{i\neq j\in I})$ is said to satisfy the elements of a DTB $\mathfrak{T} = (\{\mathcal{T}_i\}_{i\in I}, \mathcal{B})$ if:

$\mathfrak{J} \models_d i : A \underset{\longrightarrow}{\sqsubseteq} j : G$ if $r_{ij}(A^{\mathcal{I}_i}) \subseteq G^{\mathcal{I}_j}$
$\mathfrak{J} \models_d i : B \underset{\longrightarrow}{\sqsupseteq} j : H$ if $r_{ij}(B^{\mathcal{I}_i}) \supseteq H^{\mathcal{I}_j}$
$\mathfrak{J} \models_d i : A \sqsubseteq B$ if $\mathcal{I}_i \models A \sqsubseteq B$
$\mathfrak{J} \models_d \mathcal{T}_i$ if $\mathcal{I}_i \models \mathcal{T}_i$
$\mathfrak{J} \models_d \mathfrak{T}$, if $\mathfrak{J} \models_d \mathcal{T}_i$ and $\mathfrak{J} \models_d \mathcal{B}_{ij}, \forall i, j \in I$
$\mathfrak{T} \models_d i : A \sqsubseteq B$ if $\forall \mathfrak{J}, \mathfrak{J} \models_d \mathfrak{T} \Longrightarrow \mathfrak{J} \models_d i : A \sqsubseteq B$

2. Decomposing

The presented optimization techniques are only actually effective in some cases with the particular structures of GCIs. Our works is eliminating GCIs as much as possible from general ontology (presented by a TBox) by decomposing an ontology into several sub-ontologies (presented by a distributed TBox). The reasoning is implemented then on these sub-ontologies (distributed TBox). The reasoning effect depends on the decomposing method of original TBox. As a result, we propose a technique called "overlap decomposition". For legibility reason, in this paper, we examine only the simplest case, decomposing a TBox into two smaller TBoxes. The general case is presented in [11].

2.1. Definitions

$(\{\mathcal{T}_i\}, \mathcal{B}_{ij})_{i,j\in\{1,2\}}$ (denoted by $\mathfrak{T}$ or $\mathcal{T}_{12}$) is an overlap decomposing of a TBox $\mathcal{T} = (\mathbf{C}, \mathbf{R}, \mathbf{B}, \mathbf{A})$, where $\mathbf{C}, \mathbf{R}, \mathbf{B}, \mathbf{A}$ are the sets of primitive concepts, primitive roles, defined concept names, and axioms respectively, if: - Each component $\mathcal{T}_i$ consists of all primitive concepts, primitive roles and defined concepts of $\mathcal{T}$, i.e., $\mathcal{T}_i = (\mathbf{C}, \mathbf{R}, \mathbf{B}, \mathbf{A}_i)$

$\mathbf{B} = \{B \mid B \doteq C)\}, \mathbf{A} = \{(C \sqsubseteq D)\}, \mathbf{A}_i = \{(C_i \sqsubseteq D_i)\}$, where $i \in \{1, 2\}$; B is a concept name, C, D, C_i and D_i are concept expressions

- $\mathbf{A}_i \subseteq \mathbf{A}$; $\cup_i \mathbf{A}_i = \mathbf{A}$ and $\cap_i \mathbf{A}_i = \emptyset$

- $\mathcal{B}_{ij}$ is a set of semantic mappings between $\mathcal{T}_i$ and $\mathcal{T}_j$. A semantic mapping is an identical relationship between two concepts (two roles) that co-occur in two axioms of different TBoxes ($\mathcal{B}_{ij}$ can be empty if $\mathbf{A}_i$ and $\mathbf{A}_j$ are "disjoint"[2]).

Thus, an overlap decomposing of a TBox $\mathcal{T}$ is a special distributed TBox, because $\mathcal{B}_{ij}$ includes only identical bridge rules. It captures all properties of general distributed TBox (as given the section above) and some particular properties (will be proposed in the following section).

We need to give a strategy for decomposing $\mathcal{T}$ into subsets $\{\mathcal{T}_i\}$ such that each $\mathcal{T}_i$ is a DL formalism of a certain ontology.

We determine the set of semantic mappings between two TBoxes by finding concepts (roles) that co-occur in two these TBoxes, and represent them in the form of bridge rules in DDL. One uses $\mathcal{B}$ to indicate the whole of the bridge rules obtained.

Example 3: $i : X \underset{\rightarrow}{\equiv} j : X$,

where, X is a concept (a role), $i \neq j, i, j \in \{1, 2\}$; $i : X$ denote a concept (role) X of TBox $\mathcal{T}_i$

The essence of this decomposing is only examine the axioms, i.e., the set of axioms of original TBox are divided into several subsets of axioms for sub-TBoxes respectively. We are concerned the axioms because their presence can lead to an ExpTime lower bound for the complexity of reasoning problem [12]. However, the large number of concepts and roles is also a difficult for maintaining, reusing and developing independently of the component ontologies.

$\mathcal{T}$

$C_1 \sqcap C_2 \sqsubseteq X$	$Y \sqcap T \sqsubseteq H$
$C_3 \sqsubseteq \neg C_2$	$C_3 \sqsubseteq X$
$X \sqcap C_4 \sqcap C_5 \sqsubseteq Y$	$\neg C_3 \sqsubseteq C_2$
$\neg C_4 \sqsubseteq \neg Y$	$\neg X \sqsubseteq \neg Y$
$Y \sqcap C_6 \sqsubseteq H$	$\neg C_5 \sqsubseteq \neg Y$

$\mathcal{T}_1$	$\mathcal{T}_2$
$C_1 \sqcap C_2 \sqsubseteq X$	$X \sqcap C_4 \sqcap C_5 \sqsubseteq Y$
$C_3 \sqsubseteq X$	$\neg X \sqsubseteq \neg Y$
$C_3 \sqsubseteq \neg C_2$	$\neg C_4 \sqsubseteq \neg Y$
$\neg C_3 \sqsubseteq C_2$	$\neg C_5 \sqsubseteq \neg Y$
	$Y \sqcap C_6 \sqsubseteq H$
	$Y \sqcap T \sqsubseteq H$

Figure 1: *A decomposing of TBox $\mathcal{T}$ and its two sub-TBoxes*

The right of Figure 1 depicts a decomposition of TBox $\mathcal{T}$ into two TBoxes $\mathcal{T}_1, \mathcal{T}_2$

2.2. Additive properties of distributed TBox in decomposing

Decomposing TBox is also presented by a distributed TBox, therefore, it take over all properties of a general distributed TBox, and there are some other besides:

We can add about interpretations "satisfying" TBoxes:

$\mathfrak{J} \models_d i : A \underset{\rightarrow}{\equiv} j : A$ if $r_{ij}(A^{\mathcal{I}_i}) \equiv A^{\mathcal{I}_j}$

$\mathfrak{J} \models_d i : A \sqsubseteq j : B$ if $r_{ij}(A^{\mathcal{I}_i}) \subseteq B^{\mathcal{I}_j}$

$\mathfrak{T} \models_d i : A \sqsubseteq j : B$ if, for every $\mathfrak{J}, \mathfrak{J} \models_d \mathfrak{T} \Longrightarrow \mathfrak{J} \models_d i : A \underset{\rightarrow}{\sqsubseteq} j : B$

Note that, all $\mathcal{T}_i, (i \in I)$ have the same set of concepts and roles of $\mathcal{T}$, so writing $i : X$ to show that we are talking about X in $\mathcal{T}_i$.

2.3. Decomposing properties

Intuitively, a decomposing $(\{\mathcal{T}_i\}, \mathcal{B}_{ij})$ of $\mathcal{T}$ is "good" if the quantity of common objects (concepts and roles) in the decomposed ontologies is smallest as possible and the number of axioms in two sub-ontologies is most equal as possible. Decomposed ontologies are consistent, they have the same domain with original ontology, because they duplicate all concepts and roles of original ontology. We infer easily that the decomposed ontologies have also the same interpretation with original ontology.

[2] $\mathbf{A}_i$ and $\mathbf{A}_j$ are called disjoint if there is not a common concept (a role) occurring in both $\mathbf{A}_i$ and $\mathbf{A}_j$.

In addition, it must have the following properties:

(1) The preservation of concepts (roles): Indeed, each concept (role) of $\mathcal{T}$ is also a concept (role) in all certain $\mathcal{T}_i$

(2) The preservation of axioms: $\mathbf{A} \subseteq \cup_i \mathbf{A}_i$. Indeed, for each axiom $C \sqsubseteq D$ of ontology $\mathcal{T}$, it is also an axiom in one of $\mathcal{T}_i$. Note that, there is not an axiom which co-occurs in two different ontologies (i.e., the sets of axioms of two different ontologies are disjoint).

(3) The semantic mappings are proposed in order to conserve the relationships of entities between sub-ontologies, they presents only identical relationships between two concepts (two roles) that co-occur in two axioms of two different ontologies. They are presented by bridge rules $\mathcal{B}$.

These three properties are easily to deduce from the definition of decomposing, it proves the preservation of syntax. They ensure that ($\{\mathcal{T}_i\}$,$\mathcal{B}$) is well represented by DDL.

(4) The preservation of semantics, i.e., $\Delta = \Delta_i$, and $\cdot^{\mathcal{I}} = \cdot^{\mathcal{I}_i}, \forall i = 1, 2; \mathcal{I}, \mathcal{I}_i$ are the interpretations of $\mathcal{T}$ and $\mathcal{T}_i$ respectively.

(5) The preservation of inference services, i.e., a concept description is satisfiable w.r.t $\mathcal{T}$ then it is also satisfiable w.r.t $(\{\mathcal{T}_i\}$,$\mathcal{B})$ and conversely.

Also from these properties, we propose two reasoning approaches with decomposed ontologies. By characterizing the decomposition form, we will show that there exists a deterministic algorithm making it possible decompose an ontology represented by DL into several ontologies represented by DDL conforming to this form. In the size of paper, we focus only on two the most important properties of decomposing, they are composed of semantic and inference preservations. The following definitions and proofs are only examined in a DTB decomposing $(\{\mathcal{T}_i\}$,$\mathcal{B})$ of $\mathcal{T}$, i.e., $\mathcal{T}$ and $\{\mathcal{T}_i\}$ have the same concepts and roles. Therefore, instead of saying "common (primitive) concepts (roles)" we use only briefly "(primitive) concepts (roles)".

Definition 5 *(Expansion)*

Expanding a concept description C can be understood as the set of concepts constructing C. Formally, expanding a concept, a concept description, an axiom is defined recursively as follows:

Expansion $Ex(.)$, is a mapping that maps a concept (a concept description or an axiom) into a set of primitive concepts and primitive roles which occur in their definitions:

- If A is an atomic primitive concept (role) or its negation, then $Ex(A) = \{A\}$
- If A is a defined concept in form $\exists R.C$ or $\forall R.C$, then $Ex(A) = \{A\} \cup Ex(R) \cup Ex(C)$
- If A is a defined concept in form $C_1 \sqcap C_2$ or $C_1 \sqcup C_2$, then $Ex(A) = \{A\} \cup Ex(C_1) \cup Ex(C_2)$
- If A is a composite concept description in form $\rho(M_1, ..., M_k)$,where ρ is a concept constructor, $Ex(\rho(M_1, ..., M_k)) = \cup_i\{Ex(M_i)\}$.
- For an axiom $C \sqsubseteq D$, $Ex(C \sqsubseteq D) = Ex(C) \cup Ex(D)$.

Definition 6 *We define a decomposing function $\#()$ (as given in [7]) from concepts and roles of original Tbox $\mathcal{T}$ to concepts and roles in $\mathcal{T}_i$ (i$\in I$) as follows :*

1.$\#(M) = (i, M)$ for all primitive concepts and primitive roles.

2.If ρ is a concept constructor (role constructor) with k arguments, then
$\#(\rho(M_1, \ldots, M_k) = \rho(\#(i, M_1), \ldots, \#(i, M_k))$.

Example 4: $\#(C_1 \sqcap \forall R.C_2)$ produces $i : C_1 \sqcap \forall(i : R).(i : C_2)$

We provide now a DTB in DDL. Firstly, ANYTHING, NOTHING denote the top and bottom concepts of $\mathcal{T}$ respectively, they are distinguished from the top (Top$_i$) and bottom (Bot$_i$) concepts of $\mathcal{T}_i$

Definition 7 *Application # for a global TB $\mathcal{T}$, generate a DTB $\#(\mathcal{T}) = (\{\mathcal{T}_i\}_{i\in I}, \mathcal{B}_{ij})$ in the language DDL,where $\mathcal{B}_{ij}$ is the set of identical bridge rules, is composed of following axioms :*

1.(*copy all the axioms of global TBox to the same local TBox $\mathcal{T}_i, i \in I$*)
$i : \#(X) \sqsubseteq \#(Y)$, for all $X \sqsubseteq Y \in \mathcal{T}$ and $\#(X) \in \mathcal{T}_i$; $\#(Y) \in \mathcal{T}_i$
2. $i : \#(X) \xrightarrow{\equiv} j\ \#(X)$, for all $X \in \mathcal{T}$, $\#(X) \in \mathcal{T}_i; \#(X) \in \mathcal{T}_j$ and $X \in Ex(\mathbf{A}_i), X \in Ex(\mathbf{A}_2)$
3. $ANYTHING \sqsubseteq Top_i$ (*ensuring that Top$_i$ is not empty*)
4. $Bot_i \sqsubseteq NOTHING$ (*restricting Bot$_i$ to always be the incoherent concept*)
5. $(i, A) \sqsubseteq Top_i$ (*ensuring that Top$_i$ is the proper local top of its IS-A hierarchy*)
6.(*ensuring that each role R is in the same domain and space of Top_i *)
$Top_i \sqsubseteq \forall(i, R).(Top_i)$ for every role R of $\mathcal{T}$ (* the space of (i, R) ia in $\Delta^{\mathcal{I}_i}$*)
$\exists(i, R).ANYTHING \sqsubseteq Top_i$ (* R is only defined in $\Delta^{\mathcal{I}_i}$*)

Definition 8 *Given two Tboxes $\mathcal{T}_i$ and $\mathcal{T}_j, i \neq j$, with their interpretations $\mathcal{I}_i = (\Delta^{\mathcal{I}_i}, \cdot^{\mathcal{I}_i})$ and $\mathcal{I}_j = (\Delta^{\mathcal{I}_j}, \cdot^{\mathcal{I}_j})$ respectively. We say that $\mathcal{T}_i$ and $\mathcal{T}_j$ are interpreted in the same domain (or $\mathcal{I}_i$ and $\mathcal{I}_j$ have the same domain) iif $\Delta^{\mathcal{I}_i} = \Delta^{\mathcal{I}_i}$ and $\cdot^{\mathcal{I}_i} = \cdot^{\mathcal{I}_i}$for all common primitive concepts (roles) of them.*

Definition 9 *Let ρ be a concept constructor whose semantic can be expressed as $\rho(\arg_1, .., \arg_n)^{\mathcal{I}} = f_\rho(\arg_1^{\mathcal{I}}, ..., \arg_n^{\mathcal{I}}, \Delta^{\mathcal{I}})$, for a function $f_\rho(X_1, ..., X_n, DY)$ whose definition contains no references to $\mathcal{I}$. Let $B_1, ..., B_n, W, \Delta$ be sets such that $W \subseteq \Delta$, and each B_j is either a subset of W or of WxW, 1$\leq j \leq n$. Then ρ is called a local constructor if f_ρ satisfies : $f_\rho(B_1, ..., B_n, \Delta) = f_\rho(B_1, ..., B_n, W)$, when it is a concept or role constructor.*

Corollary: *If two Tboxes T_i and T_j are interpreted in the same domain, then we have $C^{\mathcal{I}_i} = C^{\mathcal{I}_j}$, for every C is an arbitrary common concept description of T_i and T_j.*
Proof. - Since $\mathcal{T}_i$ and $\mathcal{T}_j$ are interpreted in the same domain, we have $C^{\mathcal{I}_j} \equiv C^{\mathcal{I}_i}$, $R^{\mathcal{I}_j} \equiv R^{\mathcal{I}_i}$ for C, R are common primitive concept and role respectively. By inducing on the structure of an arbitrary concept (role) B, we easily show that $B^{\mathcal{I}_j} \equiv B^{\mathcal{I}_i}$.

- For arbitrary common concept descriptions M, they will be constructed from the common primitive concepts (rôles). Suppose M having the form $\rho(M_1, ..., M_k)$, where concepts $M_i, ..., M_k$ are less complex than M, and occur also in $\mathcal{T}_j$, ρ is a concept constructor taking k arguments.

By structural induction on M, we obtain $M_p^{\mathcal{I}_j} \equiv M_p^{\mathcal{I}_i}$ for all $p = 1, .., k$. We need now show that $M^{\mathcal{I}_i} = M^{\mathcal{I}_j}$. Indeed,
$M^{\mathcal{I}_j} \equiv (\rho(M_1, ..., M_k))^{\mathcal{I}_j} \equiv f_\rho(M_1^{\mathcal{I}_j}, ..., M_k^{\mathcal{I}_j}, \Delta^{\mathcal{I}_j}) \equiv f_\rho(M_1^{\mathcal{I}_i}, ..., M_k^{\mathcal{I}_i}, \Delta^{\mathcal{I}_i}) \equiv (\rho(M_1, ..., M_k))^{\mathcal{I}_i} \equiv M^{\mathcal{I}_i}$. ■

3. Parallel Reasoning

We examine the satisfiability testing of a concept C w.r.t $\mathcal{T}$ and w.r.t $(\{\mathcal{T}_1, \mathcal{T}_2\})$.

In order to test the satisfiability of concept C w.r.t $(\{\mathcal{T}_1, \mathcal{T}_2\})$, we implement simultaneously and independently normal tableaux algorithms $\mathbf{T}_1(C)$ and $\mathbf{T}_2(C)$ on the TBoxes $\mathcal{T}_1$ and $\mathcal{T}_2$ respectively. Resulting:

1. If $\mathbf{T}_1(C)$ is unsatisfiable or $\mathbf{T}_2(C)$ is unsatisfiable then we conclude that C is also unsatisfiable w.r.t $\mathcal{T}$.

2. Else, i.e., all $\mathbf{T}_1(C)$ and $\mathbf{T}_2(C)$ are thus satisfiable then we make a merging $\mathbf{T}_1$ and $\mathbf{T}_2$, denote $\mathbf{T}_1 \oplus \mathbf{T}_2$,as follows:

After tableau calculating on $\mathcal{T}_1$and $\mathcal{T}_2$, two model trees AM_1 and AM_2 are respectively generated. Each non-clash node in AM_1 is joined with all non-clash nodes in AM_2 by pairs, generating new nodes in a merging model tree.

Suppose that AM_1 have m non-clash leaf nodes, AM_2 have n non-clash leaf nodes (m,n are non-negative integers), then $m.n$ new nodes will be generated in merging tree. If all these $m.n$ nodes in the merging tree are together clashes then we conclude that C is unsatisfiable w.r.t $\{\mathcal{T}_1, \mathcal{T}_2\}$, otherwise we conclude that C is satisfiable (i.e., if it exists at least a node that is non-clash, then we conclude that C is satisfiable).

Merging two nodes x_{T_1}-label $\mathcal{L}(x_{T_1}^C)$ and x_{T_2}-label $\mathcal{L}(x_{T_2}^C)$ into a node $x_{T_{12}}$-label $\mathcal{L}(x_{T_{12}}^C) = \mathcal{L}(x_{T_1}^C) \cup \mathcal{L}(x_{T_2}^C)$, according to the following principles:

i) $\exists R.C_1 \in \mathcal{L}(x_{T_1}^C)$ and $\exists R.C_1 \in \mathcal{L}(x_{T_2}^C)$, then the union of these labels consists of a node $x_{T_{12}}$-label $\mathcal{L}(x_{T_{12}}^C) = \mathcal{L}(x_{T_1}^C) \cup \mathcal{L}(x_{T_2}^C)$, and an edge-label R between $x_{T_{12}}$ and a node $y : \{C_1\}$

ii) $\exists R.C_1 \in \mathcal{L}(x_{T_1}^C)$ and $\exists R.C_2 \in \mathcal{L}(x_{T_2}^C)$, then the union of these labels is composed of $x_{T_{12}}$-label $\mathcal{L}(x_{T_{12}}^C) = \mathcal{L}(x_{T_1}^C) \cup \mathcal{L}(x_{T_2}^C)$, and an edge-label R between $x_{T_{12}}$ and a node $y : \{C_1, C_2\}$

iii) $\exists R_1.C_1 \in \mathcal{L}(x_{T_1}^C)$ and $\exists R_2.C_2 \in \mathcal{L}(x_{T_2}^C)$, then the union of these labels consists of a node $x_{T_{12}}$-label $\mathcal{L}(x_{T_{12}}^C) = \mathcal{L}(x_{T_1}^C) \cup \mathcal{L}(x_{T_2}^C)$, and two edges that one-label R_1 between $x_{T_{12}}$ and a node $y_1 : \{C_1\}$,and other-label R_2 between $x_{T_{12}}$ and a node $y_2 : \{C_2\}$

iv) $\exists R.C_1 \in \mathcal{L}(x_{T_1}^C)$, $\forall S.C_2 \in \mathcal{L}(x_{T_2}^C)$ and $R \sqsubseteq S$, then the union of these nodes is composed of node $x_{T_{12}}$-label $\mathcal{L}(x_{T_{12}}^C) = \mathcal{L}(x_{T_1}^C) \cup \mathcal{L}(x_{T_2}^C)$, and an edge-label R between $x_{T_{12}}$ and a node $y : \{C_1, C_2\}$.
where R, R_1, R_2 and S are role names; C_1 and C_2 are concept names.

Example 5: Merging two nodes with labels $\{C, D, \exists R.C_2, \forall R.C_3\}$ and $\{C, \exists R.C_4, \forall R.C_3, \exists R_1.C_5\}$ of trees $\mathbf{T}_1$ and $\mathbf{T}_2$ respectively (Figure 2)

Input: $Tab_1(C), Tab_2(C)$
Output: Satisfiable / Unsatisfiable

```
BEGIN
T1 = Tab1(C);
T2 = Tab2(C);
T = ∅; k = 0;
For each open branch β1 in T1 do
    for each open branch β2 in T2 do
        αk = β1 ∪ β2;
        T = T ∪ αk;
        k = k + 1;
    end for
end for
If ((T1 is clashed) or (T2 is clashed)
 or (T is clashed)) then
  return unsatisfiable
Else
  return satisfiable
END.
```

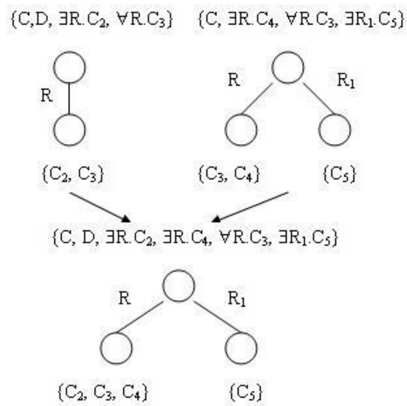

Figure 2 : *Merging two nodes of T_1 and T_2*

4. Reasoning in Distributed Description Logics

We examine the satisfiability testing of a concept C w.r.t $\mathcal{T}$ and w.r.t $(\{\mathcal{T}_1, \mathcal{T}_2\}, \mathcal{B})$.

Initially we implement the tableau algorithm $\mathbf{T}_1(C)$ and $\mathbf{T}_2(C)$ on two TBoxes $\mathcal{T}_1$ and $\mathcal{T}_2$ simultaneously (in parallel). One also will get two cases following:

1. IF $\mathbf{T}_1(C)$ or $\mathbf{T}_2(C)$ is unsatisfiable (i.e., all the leaf nodes of $\mathbf{T}_1(C)$ or of $\mathbf{T}_2(C)$ are the clashes) then we conclude that C is also unsatisfiable w.r.t $\mathcal{T}$.

2. ELSE (both $\mathbf{T}_1(C)$ and $\mathbf{T}_2(C)$ are satisfiable, i.e., there exists at least a clash free leaf node of $\mathbf{T}_1(C)$ and one of $\mathbf{T}_2(C)$), then we continue applying the tableau algorithm on $\mathcal{T}_2$ for the leaf nodes of $\mathbf{T}_1(C)$ using the identical bridge rules, i.e., $\mathbf{T}_2(\mathbf{T}_1(C))$ is applied only with non-clashes leaf nodes of $\mathbf{T}_1(C)$. Some axioms of $\mathcal{T}_2$ influenced by bridge rules between $\mathcal{T}_1$ and $\mathcal{T}_2$ are added to the constraint system for $\mathbf{T}_2(\mathbf{T}_1(C))$.

Input : $dTab(C)$
Output : Satisfiable /Unsatisfiable

```
BEGIN
T = dTab(C) ;
If T = Tabj(C) then {execute the local reasoning in Tj and generate the complete tree}
      for each open branch β in T do
            repeat
                  select node x ∈ β and an i ≠ j ;
                  iidtq(x) = {D|j : D → i : D, D∈L(x)}
                  if ( iidtq(x) ≠ ∅) then
                  for each D∈ iidtq(x) do
                  if (dTabi(D)) is not satisfiable then
                           close {clash in x}
                         break; {verify next branch}
                    end if
                 end for
               end if
            until (( is open) and (there exist not verified nodes in ))
      end for {all branches are verified}
end if
if (T is clashed) then
      return unsatisfiable;
else
```

22: return satisfiable;
23: end if
24: END

Theorem *(Soundness and Completeness)*

Given a TBox $\mathcal{T}$ and its decomposing presented as a distributed TBox $\mathcal{T}_{12} = (\{\mathcal{T}_i\}_{i \in \{1,2\}}, \mathcal{B}_{ij})$, then $\mathcal{T}_{12} \models_d i : X \sqsubseteq j : Y \Leftrightarrow \mathcal{T} \models X \sqsubseteq Y$, where X, Y are concepts in $\mathcal{T}$.

The proof are detailed in [11]. We brief as follows:

In the direction of $(\Rightarrow)$: $\mathcal{T}_{12} \models_d i : X \sqsubseteq j : Y \Rightarrow \mathcal{T} \models X \sqsubseteq Y$

Let $\mathcal{I}$ be an interpretation that satisfies $\mathcal{T}$ $(\mathcal{I} \models \mathcal{T})$, with the domain $\Delta^{\mathcal{I}}$,we need show that $\mathcal{I} \models X \sqsubseteq Y$ (or $X^{\mathcal{I}} \subseteq Y^{\mathcal{I}}$).

- Starting from $\mathcal{I}$, we construct $\mathfrak{J} = (\{\mathcal{I}_i\}, \{r_{ij}\})$, where $\mathfrak{J}$, $\mathcal{I}_i$ is an interpretation with the domain $\Delta^{\mathfrak{J}} = \Delta^{\mathcal{I}_i} = \Delta^{\mathcal{I}}$ (i.e., $\mathcal{I}, \mathcal{I}_i$ and $\mathfrak{J}$ are in the same domain) respectively (for all $i \in I$). $\mathcal{I}_i$ interprets each primitive concept (rôle) (or special concept ANYTHING) (i, C) of $\mathcal{T}_i$ according to the rule $\#(C)^{\mathcal{I}_i} = C^{\mathcal{I}}$ and $\{r_{ij}\}$ are identical relations, i.e., $r_{ij}(C^{\mathcal{I}_i}) \equiv C^{\mathcal{I}_j}$, for all identical bridge rules.

Firstly, we prove $M^{\mathcal{I}} = \#(M)^{\mathcal{I}_i}$ (using the corollary above) for arbitrary concept description M of $\mathcal{T}$. Then, we show that $\mathcal{I}_i$ is an interpretation of $\mathcal{T}_i$ $(\mathcal{I}_i \models \mathcal{T}_i)$ and $\mathfrak{J}$ is an interpretation of $\mathcal{T}_{12}$ $(\mathfrak{J} \models \mathcal{T}_{12})$.

- From assumption, we have $\mathfrak{J} \models i : X \sqsubseteq j : Y \Rightarrow \#(X)^{\mathcal{I}_i} \subseteq \#(Y)^{\mathcal{I}_j} \Rightarrow X^{\mathcal{I}} \subseteq Y^{\mathcal{I}} \implies \mathcal{I} \models X \sqsubseteq Y$

Similarly for the direction $(\Longleftarrow) \mathcal{T} \models X \sqsubseteq Y \Longrightarrow \mathcal{T}_{12} \models i : X \sqsubseteq j : Y$.

5. Conclusion and future works

The previous optimizations are only effective in certain knowledge bases. Decomposing an ontology into smaller ontologies contributes to improve the speed of reasoners with all knowledge bases in DLs, as shown by the results we have given above. We have shown that reasoning in decomposed ontologies preserves the reasoning results of original ontology. In this paper, some essential properties of decomposing that influence the reasoning performance have also been provided. We are studying to find an effective and optimizing algorithm for this decomposing. This again depends on having an effective (and cheap) method for analyzing the likely characteristics of a given test ontology. We are also performing more experiments with very large KBs (as UMLS,...) for showing the effect of reasoning over decomposed ontologies. Reasoning results in the decomposed ontologies by combining both of parallel and distributed methods will be the subject of a future paper. We are embarking in the optimizing of decomposition algorithm and treating the queries effectively in DDL. Also, an efficient solution for decomposing into several sub-ontologies and reasoning over those sub-ontologies will be proposed.

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Knowledge and object phylogenetic production cascades - the TELOS case

Ioan Rosca
Information, instruction and telecommunication systems engineer
LICEF-Teleuniversity of Montreal, Canada
ioan.rosca@licef.teluq.uqam.ca

Abstract. In the unitary design of systems involving people, objects, processes and concepts, the engineering acquires a hybrid character, requiring the coagulation between the contributions based on diverse expertises and posing coordination and communication problems inside mixed design teams. The LORNET project federates research institutions from Canada for the construction of a “middleware” supporting technical and semantic inter-operation between campuses and repositories distributed on the Internet. It is a double challenge: an effort of concurrent research for instrumenting the instructional concurrent engineering. Observing the circle between "doing by learning" and "learning by doing", activity coordination systems can be enriched with a "semantic layer" (facilitating the procedures execution by alleviating their comprehension and learning). Reciprocally, the production and management of distributed pedagogical activities require collaborative procedure modelling and orchestration. This paper is addressed to those seeking different perspectives in dealing with complexity. I summarize it as follows: mixing the management of persons, objects, processes and knowledge; using the procedures' models for their orchestration; approaching a “4d” vision for extending the observation of short process (“ontogenetic” and “physiological”) to those of long-term evolutions; unitary management of phylogenetic cascades- reproducing structures and processes- based on metafunctions.

Keywords: instructional systems engineering, semantic indexed procedures, phylogenetic production cascades, LORNET, TELOS

Introduction

Although I do not actively take part in the scientific life of the CE community, the consulted papers enable me to see the connection between the problems that preoccupy this interdisciplinary domain and the problems I faced as an architect and coordinator… of teams producing systems and knowledge… usable for the production of systems and knowledge… usable for the production of knowledge and systems … I'm counting on the expressiveness of narrating my experience to point out intuitions and proposals - instead of launching myself in an analysis of the literature of a domain that I do not claim to master. For this reason, I will not resort to the usual bibliographical explorations (specifying only the last readings that influenced this paper - as, for example [1a, b] and signalling personal texts- which extend ideas briefly exposed here).

1. Between to do, to know and to learn

1.1. Procedure for knowledge… or knowledge for procedures?

The encounter between these two trends in fields like "pragmatic web" [2] is natural and I had been waiting it for a long time. I have realized the indissoluble link between information (learning) management and activities management for the first time - as coordinator of the vocational training system of a large electronics company (television sets, computers etc). Trying to organize an infrastructure for combining instruction, information and support, I found myself in a difficult posture. I discovered that the "technology of instruction" rises problems as: "With what strategies and tools should we equip the technologists A and methodologists B, which wish to supply (with composition and management methods and instruments) a public of authors C and managers D, which organize instructional systems, in which a group of assistants E can instruct a group of learners F so that they obtain an amelioration G of their competences in the knowledge domain H, necessary to accomplish the performances I in the contexts J- … all that optimally, according to criteria K, verifiable by the methods L".

In the meantime I have learned that the engineering of objects and knowledge cannot be untwined. Knowledge is produced in activities instrumented with objects. Their construction is accomplished through communication and coordination- which is based on semantic synchronization. At the base of this loop stands the relationship between "doing to learn" and "learning to do". In order to do, you must know. But for that, you must exercise, doing- learning, climbing up the "experience" spiral. Therefore, the concept of "assistance" - covers a large range of significations. It can mean to "inform" –delivering an opportune and intelligible message. When the understanding process meets difficulties- "clarifications" are required. If necessary, the beneficiary is helped to "learn" the information- in order to be able to reuse it anytime. In the place of explicative messages (what is to be done, how, with what instruments)- new tools can be provided ("equipment") or the use of the existent ones can be "facilitated".

After many years of practice and meditation, I have reached the conclusion that the concept of *explanation* can facilitate the fusion between instruction and assistance and that the foundation of the "instructive-productive management" should be a unitary theory of procedure modelling- including material and cognitive aspects. I have exposed the objectives and principles of such a science in my doctoral thesis [3]. I will only signal in this intervention the aspects related to the cooperative design of evolving systems implying evolving knowledge (embodied in evolving participants and referred in modifiable message supports).

The connection between knowledge and the entities that incorporate it must be correlated with the observation of dualities such as: structure/process, existence/transformation, adaptation/evolution, ontogenesis/phylogenesis. The physical and conceptual entities, tied by relationships, create systemic units and determine their behaviour (physiology). Conversely, the physical and cognitive processes sediment structures (entities and relations). A complete systemic vision must reveal the existence-becoming duality. The adaptation and evolution of a structure are intimately tied, defining its "life", as systemic entity. The ontogenesis of the being (of the individually experienced concept, of the object) and the phylogenesis of the species (of the collectively experienced concept, of the object production cascade)- are interlaced processes.

In the same way a cell's metabolism coexists and interferes with the metabolism of the organism it belongs to, the individual cognitive metabolism is "situated" in that of the community [4]. Explicative communication can be seen as a relationship between two distinct cognitive systems, but also as a manifestation of the cognitive physiology of the human species' system, ensuring knowledge reproduction.

What derives from these systemic considerations?

The proposal to replace the concept of “concurrence” with that of “coexistence” and "co-evolutivity". The perception of the “4d” character of systems moves the accent from “reengineering” to the longitudinal management of their evolution [5]. As for the continuous evolution of the participants, what can better highlight it than the observation of the "learning" phenomenon?

1.2. Semantic matching for co-action and explicative communication

The key to the coordination of (design) processes is the co-operation between participants. Sometimes, it can be solved by distributing the tasks, other times it asks the demonstrative sharing of certain operations. In any case, it supposes semantic consonance. The engineering of concurrent processes involving people cannot avoid the communication problem and the partition of meaning.

Although dealing intensively with modelling co-operation and negotiation (examples in [6,7]), domains like CSCW, DSS or CE have studied insufficiently the specific of explanatory cooperation- in which the expert does because he knows and the novice knows progressively- because he is helped to do. It isn't just about concatenating two operations, because the "pas de deux" execution draws its sense from the processes fusion.

What role can intermediary artefacts have in these bi-human processes? To what extent can they take part in to the dialogue (as "intelligent agents") or instrument it? As co-action and communication partner, the human assistant has intrinsic qualities - difficult to mechanize. The assistants' "artificialisation" is problematic - practically and ethically. But prior to cooperating or communicating, the partners must equip, find and agree themselves. And after, they must update the model that sustains their coordination. Instead of degrading the explicative dipole, the synaptic infrastructure based on the computer network can provide contact, contract and management services. Activity coordination systems (production, instruction, engineering) of CSCW type could be enriched with matching facilities: selection of participants that can perform (optimise) the ongoing operations' chain.

This requires the "indexation" of all elements (available persons and resources, actors and generic instruments specified in the activities' scenarios) relative to a "knowledge domain" K, used as a reference system [8]. In a support (instruction) system, the evolution of the subjects' understanding must be observed. We use "*competences*" C (descriptions of someone's position relative to knowledge): "mastering levels"- measured on a metric scale M or qualitative "abilities"- as *knowledge/ comprehension/ application / analysis/ synthesis / evaluation)*. In order to observe the competence equilibrium around pedagogical operations [9] I have introduced "postures" as: (*knowK, aimK, explainK(x,y), describeK(x,y), evaluateK(x,y), recommendK(x,y)*)- where the parenthesis show a predicate depending on the detained (x) or aimed (y) "mastering level" of the person (learner etc) to which the described participant could explain the knowledge k.

The organization of the K-C layer stands at the foundation of the global physiology of the knowledge system involved by a project, an evolving system or a community. Semantic indexation (knowledge and competences) of participants and documentary resources will facilitate their retrieval (in the case of emergent activities) or their connection (when the activities are orchestrated through adaptable predefined scenarios).

1.3. Managing a project seeking project management tools…

I had the occasion to study the relationship between supporting learning and action in some research projects: SAFARI (an ITS authoring system), EXPLORA (a virtual campus management platform, MOT (a knowledge structure, pedagogical scenario and resource conception/diffusion editor - IMS-LD compatible), ADISA (Distributed Workbench for Learning Systems Engineering - allowing their complete planning according to the MISA method), SavoirNet (the transition of EXPLORA towards a service provider position), VAL-GEFO (a cooperative pedagogical workflow manager) [10]. But the fusion of this vast problem space was imposed by the task of conceiving the TELOS system (distributed pedagogical tele-learning operating system) in the LORNET (learning object repository network) project (launched in 2003 and holding until 2008).

My activity in LORNET (2003-2005) as conceptual architect has enforced my belief that the methods and tools used in the management of such complex projects should be perfected. An interesting (and somewhat paradoxical) engineering situation is created - in which the formulas and instruments produced in a project can be useful in the organization of their construction. The occurrence of this "vicious circle" can produce a certain epistemological perplexity, but it also opens the way of refined and fertile strategies for ascending the research-development-application spiral.

But I haven't found yet a satisfying theoretical frame to approach the matter of recursive management and meta-management (managing the process of conceiving a system for managing the evolution of the A-B pair formed by a system A and a management instrument B…). I also haven't assisted often to descriptions of projects envisioning management methods- that were organized by the proposed methods, of procedures for process modelling, modelled by their own formula etc. Why do we invite others to consume medication (instruments) that we do not use in analogue situations? Could it be that some profound causes are hidden here? Insufficient observation of costs involved by the management efforts hides optimisation paradoxes?

2. The loop between a procedural reality and its model

I have defined the TELOS conceptual architecture [11] so that it sustains the modelling and management of distributed instruction activities: from the emergent ones (searching human and material support and chaining operations freely) to the orchestrated ones (through rigid or adaptable scenarios). Sometimes, users prefer the freedom to choose the pertinent resources (support tools and persons, previously "published" in directories and repositories). In other situations, instead of loosing time to find resources or order operations, users can rely on already prepared "aggregates", edited by an author at a previous stage [12]. These combinations assemble the resources appropriate for solving a problem, according to various formulas. "The

Collection" - is a set of resources, equipped with management instruments (interfaces). "The Fusion" - composes a system from interdependent resources, forming a unitary whole. "The Operation" - aggregates an action, its executor, support actors and support or target resources. "The Function" - is a procedural aggregation, the required resources being connected to the operations decomposing the activity that it models or orchestrates [10,13]. The structural or procedural aggregation can continue recursively, leading to more and more complex resources.

A rising interest is manifested for the representation and instrumentation of procedures, both as design target and as its instrument [14,15]. The use of models can be a way for their management, orchestration or reproduction. The functions allow the representation of short processes ("events") but also of “longitudinal” evolutions. For instance, they can represent a resource (aggregate) lifecycle chain (edition, progressive concretisation, run-time adaptation and use, annotation and feed-back).

When the object pursued by such a model M is also a model m (for example a function)- we can emphasise the reciprocal influences between the modelled reality r and the model m (occurring for example during the model composition inspired by the reality or when the phenomena's model m is used as an instrument by the participants to an actual r process). The global physiology of the "reality-model" pair can be followed (managed) with the help of metafunctions (also see a similar approach in [16]). These ones capture the evolution of the relationship between an assisted system A and a supporting system B: the request, definition and construction of B (from A), the adaptation (particularization) of B for various versions (contexts) of A, the use of B (towards A) and finally the annotations and the eventual corrective reactions. The P(f(p)) process of managing such a f(p) "functional model" for a procedure p (from its edition to its use) - can at its turn be modelled and orchestrated with the help of a "metafunction" F(P(f(p))).

Figure 1 represents the global process of reproducing primary phenomena, modelling them and using these models to create more or less similar secondary phenomena (procedure "phylogenesis")- synthesizing the use cases of the GEFO function manager.

1 **Modelling.** A primary procedural phenomena P is observed (imagined) by the designers that edit its model.. 2 **Reproduction.** The primary phenomenon P is reproduced in a number of secondary phenomena S, through the execution of the model, which can mean 2a The model is used as an informational (explicative) guide, inspiring the actions, facilitating the sequencing etc. 2b The participants declare (annotation) and produce (trace) data relative to the exploration- memorized by the model and used for reactions (verifications, support etc). 2c The model is used as an interface for launching and controlling some resources, facilitating their manipulation (procedural aggregation) 2d In the case of cooperative use, the model can facilitate the participants' communication and coordination (floor-control, signalling, etc). 2e If it is semantically indexed, the model can provide retrieval, selection and alerting services, sustaining the run-time concretisation of the components (matching role). 3 **Meta-modelling.** Observing (imagining) the primary process 1 of the model's editing (or of the P-1-2-S chain of reproducing procedures with the model help), some process engineers can edit meta-models- useful for modelling, explanation or support. **4 Meta-reproduction.** Using meta-functions (in the: a,b,c,d,e sense), the primary process 1 of function editing can be reproduced (with variations) in secondary editing processes 1S- producing functions usable in the chain 2-S.

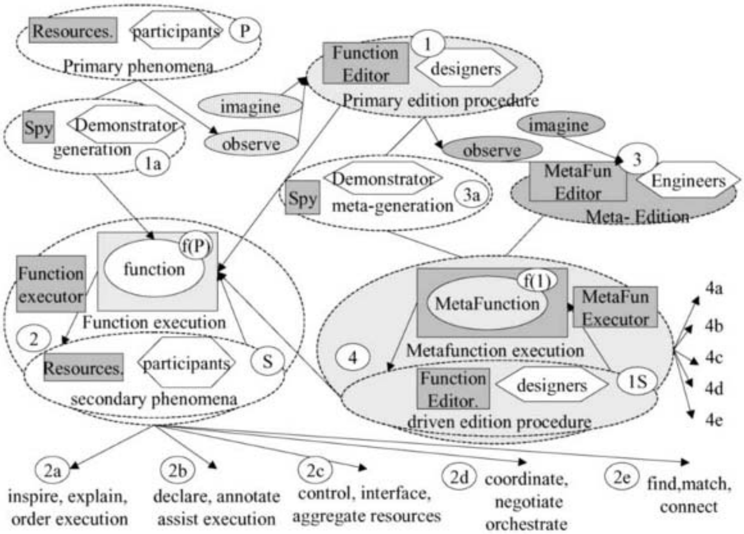

Figure 1. The procedures' phylogenetic reproduction chain

3. The meta-engineering of "phylogenetic" production cascades

The meta-process exposed above can explain (manage) the reproduction of processes and structures. But the "ontogenetic" operations can also be chained by "production cascades": the resources resulted from a process being used (as raw material or instrument) in the other. The questions signalled in paragraph 1.1 have stirred my interest for the meta-engineering of the longitudinal chaining of "lifecycles", conforming to a "phylogenetical" approach: to prepare "grand-grand-mother" systems that can produce "grand-mother" systems with which "mother" systems can be conceived, able to generate the desired knowledge "children".

The ambition of the systemic approach is therefore paid by confronting complexity (perplexity). A rigorous resolution is problematic. Even when it is possible, the energy expenses can surpass what is gained from it. The impressive number of: elements and phases, aspects and dimensions, criteria and methods, contexts and versions – require the simplification of the models, strategies and instruments, according to a "pragmatic" orientation: get the most useful services through the most accessible means, seeking the optimisation of the effort/result ratio – when the resources are limited. I have orientated the TELOS conceptual architecture [6,9,10] on such pragmatic criteria, segmenting the following phases of the TELOS main production chain:

LKMA use - to produce knowledge and LKMP. The system's target-process is the use of learning or knowledge management applications (LKMA) by learners (eventually assisted by facilitators)- to improve their competences and eventually produce some material results- traces, notes, objects- (forming knowledge management products- LKMP, which can be managed in system libraries or in user portfolios).

LKMS use- for producing LKMAs (lessons, support tools etc). An important case of (functional) aggregate "ontogenesis" is the construction of an application scenario (LKMA) using an authoring tool (learning and knowledge management

system - LKMS). The recursive situation shows up: the design procedure produces a model that will pilot the (re)production of another procedure. Thus, the participants to this phase can also learn, cooperate, produce traces and notes, receive support from specialized persons or use assistance tools.

Core use- for producing LKMS (instructional systems, authoring tools, etc) Another important ontogenetic chain is the construction of an LKMS with the instrument toolkit available in the TELOS core, its particularization for various beneficiaries (that will use it for the conception of LKMAs.) The LKMS design can be managed as a complex aggregate composition. Thus we can observe operations as: finding components, making notes, producing traces, receiving help, learning, cooperating etc.

Core modification and longitudinal management. Core administrators manage the content of system libraries and handlers: document and tool repositories, participant directory records (eventually enriched with person "interfaces"), aggregate repositories (fusion, collections etc), operation and function models (abstract, concretised or adaptable), LKMS, LKMA and LKMP areas. The *"genetic" character of the production cascades* becomes visible observing the object "circulation": a component produced by the system core engineers can be adapted and incorporated in an LKMS, then placed into an LKMA - from where it can finally get into an LKMP.

Figure 2 (extracted from the TELOS documentation)- illustrates the TELOS operations described above and adds the level of the LORNET research team, building the TELOS system: the educational researchers- establishing the project specifications and the evaluation scenario, the system engineer- producing the conceptual architecture and the scheduling, the technical architect- designing the architecture and piloting the development team, the technical evaluators- observing the system behaviour and the pedagogical evaluators- watching the qualities of learning experiences realized with the aim of the LKMA… produced with the LKMS… designed with the core tools.

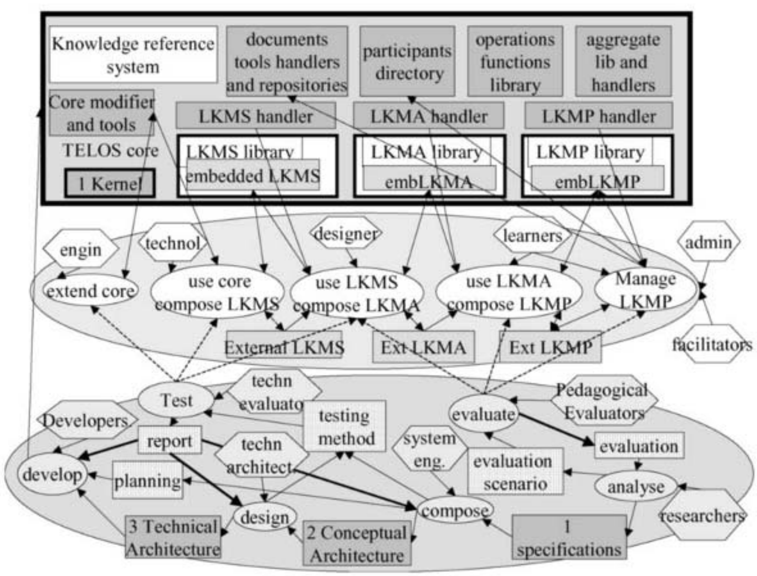

Figure 2. TELOS and LORNET blended physiologies

Organized as a "meta-function" (with connected resources, indexed on a meta-ontology and implementing ordering, coordination and assistance mechanisms) - this scheme could have become a dual-project management tool (instrument and proof of concept). That is why we have used [10] the GEFO manager to illustrate the desired behaviour of the TELOS system. That is also why we could adopt and enrich the RUP software engineering method [11] - axed on "use-case" management- during all development phases.

I hope that this succinct account will instigate the interest of the CE community for the instructional engineering. On one hand, this domain reveals similar problems to those encountered by the engineering of any complex system. On the other, any systemic metabolism implicating human protagonists involves an evolving distributed knowledge system. The physiologies of these two reality layers are too intimately correlated to justify their separate optimisation (engineering).

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Knowledge Management to Support Lean Product Development

Alan HARRIS, Ahmed AL-ASHAAB, Chike ODOUZA
School of Engineering and Built Environment, Wolverhampton University, Wulfruna Street, Wolverhampton, WV1 1SB, England. *A.Al-ashaab2@wlv.ac.uk*

Abstract. With NPD/I, there are no hard and fast rules to determine the length of such projects and quite often over a 10-year period several hundred projects could come into being, and this quite often coincides with huge advances in technology over the same period. This advancement in technology has often taken over the role of the designer carrying out calculations and providing solutions. This has resulted in certain cases; designers having very little to no understanding or practical experience of the manufacturing processes and the design calculations required to ratify product designs. The resultant loss of information and intent and the lack of exploitation of manufacturing constraints and product knowledge can and quite often lead to product re-design and in some cases failure in the hands of the customer. Research carried out here has studied knowledge management and the knowledge required to support the development of new products within the cold roll forming industry and analyses whether knowledge management to support product development can be defined as lean product development.

Keywords. Knowledge Management, Lean Product Development, Cold Roll Forming

Introduction

Industry is changing faster now than at any other time in history, with increasing market requirements, global competition and an increasing emphasis on quality, cost and reliability [1].Development of new products is now considered fundamental for corporate growth and sustained competitive advantage, this is due to increased competition that organisations face, the rapid development of technology, and shortened product life cycles [2] Product development is becoming increasingly important in the way organisations work and are structured, technology is a major factor in this and during the last 20 years, automation and computerisation have advanced dramatically and have brought about fundamental changes in the work place as manual highly intensive work has been replaced by fully automated non-operator processes. The rapid advance in technology has seen a huge increase in the number of commercially available computer based development tools, however many of these tools are individual systems with particular stand alone functionality, which lack the capability to support decision making within the product development process This has led to designers having very little or no understanding or practical experience of the manufacturing processes and the design calculations required to ratify a product or

process. The loss of engineering knowledge and the lack of exploitation of manufacturing constraints and the product development process can cause consistency problems in the design and manufacturing industry, resulting in product and process re-design or even failure in the hands of the customer Many organisations are poorly equipped to tackle this problem and it is often compounded by the fact that these organisations are highly bureaucratic with functional structures that inhibit the free flow and processing of information.

As a response to this increasingly dynamic and challenging environment, a robust, efficient, effective product development process must be in place to support business sustainability and growth. On the other hand, an organisation's engineering knowledge and past experience must be captured, cultivated, shared, protected and utilised within future product development projects to maintain its competitive advantage as well as its intellectual property. This paper describes a manufacturing company within the metal forming industry, that produces cold roll formed profiles for application in several market sectors including, commercial vehicles, yellow goods, steel bridge construction and storage and racking systems, and how they have gone through the early stages of applying lean principles in order to speed up the new product development process. The paper will detail the problems identified and how they have lead to the question: Is Lean Product Development, product development in a knowledge based environment?

1. Adopting Lean Principles to Product Development

In today's markets, it is becoming more apparent, that organizations need to manufacture quality new products quicker and be more cost effective than there competitors. Consequently, focus has begun to shift from manufacturing and its many strategies, i.e. lean manufacturing [3]and are now becoming much more focused on the design and development of new product and its integration into the manufacturing process.

There are significant amounts of literature available both commercially and academic that detail the improvements organizations have made by applying lean concepts to there manufacturing facilities, due to this success lean concepts are now being considered and adopted into other processes and different market sectors [4], in particular product development.

Lean concepts were derived from the Toyota Production System which was the result of many improvements initiated as far back as the 1940's by Taiichi Ohno. The 1950's also saw the beginning of a long collaboration between Toyota and Shigeo Shingo who helped refine earlier efforts of lean concepts into an integrated Manufacturing Strategy [5]

Lean in simple terms is defined as: producing what is needed, when it is needed, in the time that is needed, with the minimum amount of resource and space. The whole objective of lean is the elimination of waste. Waste in terms of lean is considered as those activities that do not add value in the eyes of the customer. In applying lean concepts a major objective is to identify value and non-value added activities. This could be also adopted for product development where any activity that would result in customer requirements being met could be considered as value added activity. Product

development activities must be formalized and structured in such a way that any engineering decisions taken are based on proven knowledge and experience. Failure to apply proven knowledge and experience could result in product and process redesign which would be seen as non-value added activities i.e. waste of valuable resource.

In order to illustrate or identify a products value added activities there is a need to represent the product development process in a value stream map. This could be done using several different modeling techniques; however in this paper the authors used the Integration Definition for Function Modeling (IDEF0) activity modeling method.

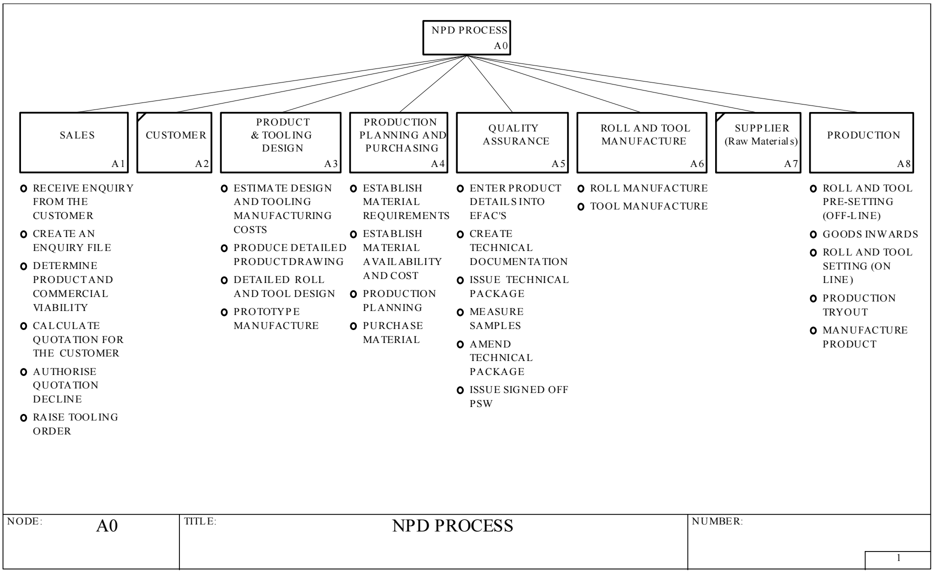

Figure 1. Top level key Product Development activities as well as the sub-activities of each department.

- using several different modeling techniques; however in this paper the authors used the Integration Definition for Function Modeling (IDEF0) activity modeling method.

The IDEF0 activity modeling helped identify the key product development activities as well as the information and material flow between them within the organization used for this research. Figure 1 is a top-level view showing departments involved and the key activities within each area.

The VSM based on IDEF as well as the face-to-face interviews with different engineers have helped to identify the following wastes in product development process:-

- No formal NPD procedures or documentation.
- Key Performance Indicator's do not measure process outputs; cost, schedule adherence and right first time.
- Poor communication resulting in delays and capacity issues.

- Little to no involvement of suppliers or production.
- Projects often started with no clear product specification/definition.
- Sales and Engineering own agendas no common goals/objectives.
- Technical experience limited to experience gained within the organization.
- Designers do not fully understand the principles of the cold roll forming process.
- High levels of multitasking and personnel turnover.
- Engineers not collocated.
- Planning and execution over dependent on time constraints and special coordination.
- Existing product data hard to find/retrieve.
- No feedback mechanism from production/Quality identifying problems associated with the product/process

From a detailed analysis of the process the following actions were identified:

- The organization needs to formalize its product development process capturing and defining only value added activities,
- and those activities need to be supported by proven engineering knowledge and experience, which needs to be identified, captured, formalized and presented in a way that will allow its utilization in future product development programs.

The authors refer to the integration of engineering knowledge into a formalized product development process as **Lean Product Development.** The following section details the importance of knowledge within product development environment, how the loss of knowledge has impacted on the organization and the steps being taken to utilize knowledge and experience to support product development.

2. Knowledge management in Product Development Environment

New product development (NPD) is a process by which an organization uses its skills and technology to create new products or to update existing ones. Product development is seen amongst the essential processes for success, survival and renewal of organizations, particularly for those organizations in either fast paced or competitive markets. Organizations performing NPD activities face pressure to reduce cycle times and development costs, without sacrificing innovation, as characterized by a faster-better-cheaper philosophy [6]

Product development activities are becoming more and more complex and require greater depth and breadth of knowledge. This knowledge needs to be modeled in a way that ensures its correct use to solve problems to solve real industrial problems [7].
Because knowledge is increasingly important for competitive advantage [8], organizations are focusing on their knowledge generating competencies. However the identification of knowledge required and the ability to utilize it is however a major

challenge facing organizations. Increasing an organizations proficiency at deriving competitive value from knowledge requires understanding of what aspects of the organization's systems and structure affect its ability to acquire, create, and apply the appropriate and necessary knowledge. Furthermore the majority of commercially available software systems used to support project collaboration and reuse of past experiences are mainly restricted to document management/sharing. Very little literature is available on what engineering knowledge is required to support product development.

Table 1: Knowledge management frameworks and associated authors.

Authors	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Holsapple and Joshi (1998) [9]	Acquisition	Selection	Internalization	Use	
Davenport and Prusak (1998) [10]	Generate	Codify	Transfer		
Mertins, Heisig and Vorbeck (2001) [11]	Create	Store	Distribute	Apply	
Kasvi, Vartianen and Hailikari (2003) [12]	Creation	Administration	Dissemination	Utilization	
Liu,Chen and Tsai (2003) [13]	Obtain	Refine	Store	Share	
Liebowitz and Megbolugbe (2003) [14]	Identification	Capture	Sharing	Application	Create - new
Lee, Lee and Kang (2004) [15]	Creation	Accumulation	Sharing	Utilization	Internalization

How to manage this knowledge has become an important issue in the research community and several authors have explored its nature, concepts, frameworks, architectures, methodologies, tools, functions, and as a result there are several frameworks that have been defined to manage knowledge. Table 1 identifies some of those frameworks and the associated authors.

In this study, knowledge in product development environment is considered to consist of four activities.

i) Identification; The identification of Knowledge required to develop new products, including product specifications, process, tooling, and material capabilities
ii) Capture; how the knowledge is captured stored and retrieved.
iii) Formalize and Present; how knowledge can be formalized and presented to ensure its use in existing and future projects.
iv) Utilization; how the knowledge identified, captured and formalized can be integrated into products and decisions, and applied in other projects.

2.1. Knowledge Management A case study within cold roll formed industry

In order to explain the evolving issue of knowledge required in product development the following section presents a typical case within the cold roll forming industry.

The organization involved in this study has been designing and producing cold rolled profiles for 75 years. The last twenty years has seen huge changes within the process, whereby software has now been developed to automatically design the necessary tooling for a particular profile examples of this software include COPRA [16] and Profil [17] virtually changing the designers' role to more of one of a CAD operator. Over the same period of time there have been huge advances in material science, in particular steel. Cold roll forming organizations are no longer restricted to producing products from mild steel. There are now several hundred material specifications, such as micro alloyed steel, which is available in several grades specified by its yield strength, examples include S355MC and S460MC [18].

The knowledge required to ratify tool design over the same period has diminished due to retirement, staff turnover and the organization has become more reliant on the design software.

Although the design software has capabilities to consider the various materials available, and can be specified, the designers do not understand the effects they may have on the cold roll forming process, and quite often utilize the default settings within the software, and a lot of their calculations to ratify the tool designs are based on mild steel.

The organization has an extensive product portfolio, with several similar products, and the sales department has attempted on several occasions to offer identical or similar products to a customer to potentially reduce lead-times and cost, without much success. One of the problems associated with the potential re-use of tooling, is that there is no real archive system or data base whereby similar products can be searched and success at finding similar products is based purely on the knowledge of its personnel. , figure 2 shows a general hierarchical structure of a possible archive system whereby a product could be searched by product type or by market sector. Further to this there is little to no mechanism to feed tooling information back to the designers from production, and therefore whether a product met all the criteria specified by the customer is impossible to clarify.

The current product development practice is mainly based around dedicated tooling, however based on an analysis of tooling costs and product development cycle within the organization the authors believe considerable cost savings and development time can be saved if products and associated tooling could be reused. Analysis of orders for product where tooling was available showed that lead-times from receipt of order to delivery of product was governed by machine capacity, and in some cases product was shipped to customers within one week. Where products had to be designed and tooling manufactured, delivery of product varied between seven weeks, and one year for more complex products.

Where products of a similar nature to standard and bespoke profiles was required, the organization attempted to create a product platform, whereby existing tooling could be used with the addition of further tooling or post operations. Tooling costs for this type of product was as much as 60% cheaper. Figure 3 shows a product/tooling cost analysis for the three product development strategies used within the organization.

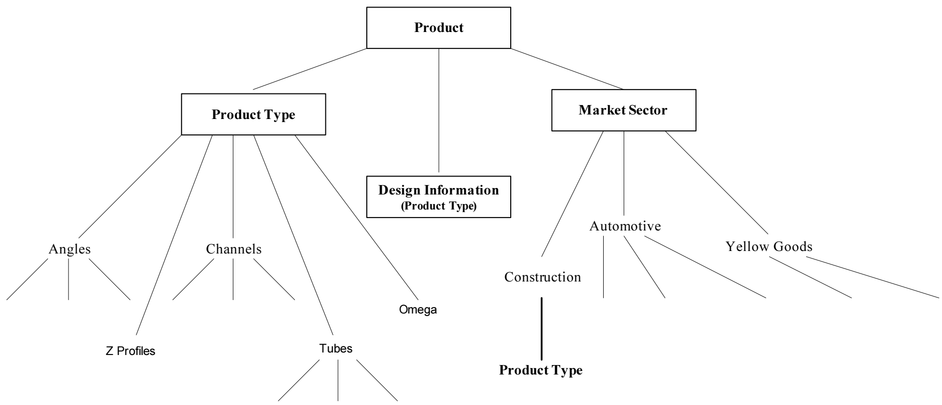

Figure 2. General hierarchical structure of an archive system for products characterized by market sector, design information and product type.

Further to this complications have been identified due to the lack of design procedures and management of resource. The design process is based on the designers own experiences and understanding and is not supported on specific engineering knowledge of machinery, process and material capabilities. The organization is very diligent at attempting to win new business, but not very good at managing the resource to complete work committed to do. As a result designers and engineers are juggling multiple projects and tasks. It is quite evident that multi tasking is causing bottlenecks, and disrupting workflow, thus resulting in inefficiency and mistakes, which in turn result in additional costs and late delivery.

In order for the organization to utilize existing products and develop further platform designed products where costs and development times are significantly lower emphasizes the need for a formal NPD model that is supported by a knowledge based system of the organizations engineering knowledge and past experience.

The next section details a case study within the organization showing how using existing knowledge and a platform designed product reduces product cost and development time.

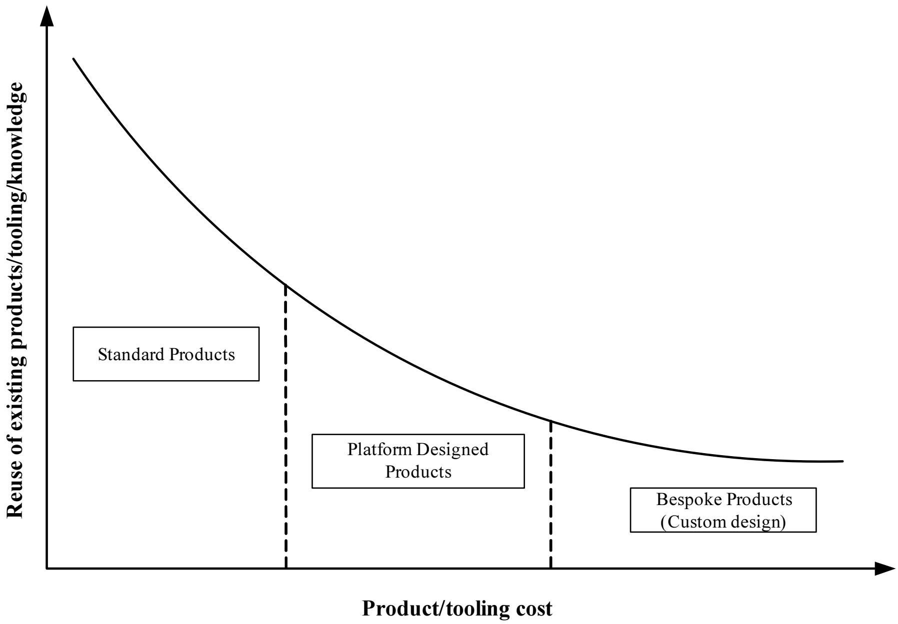

Figure 3: A product/tooling cost analysis for the three product development strategies used within the organization.

3. Lean Cold Roll Forming Product Development

3.1. Cold Roll Forming Process

Cold roll forming is a means of forming flat metal strip into various profile shapes by means of forming rolls; figure 4 shows a typical forming pass and a cross section showing how the material behaves during forming. The strip passes between the top roll and the bottom roll, which are shaped to give the correct form required for that particular part of the forming process.

As shown in figure 4 each element of the material, the edge of the strip, the radius and the bottom centre line all travel through the forming rolls on a different plane to the Z axis to which they originally started, this is due to various degrees of deformation. The edge of strip_between points 1 and 2 begins to stretch in the Z plane (longitudinal forming direction), as well as bending in the YZ plane in the positive Y direction. The radius element undergoes a gradual bending in the XY plane thus forming the required radius, as the radius is formed plastic deformation of the material increases from point 1 to a maximum at point 3 where the material passes through the forming rolls. The base line element undergoes to a somewhat increased degree the same deformation as the element in the radius.

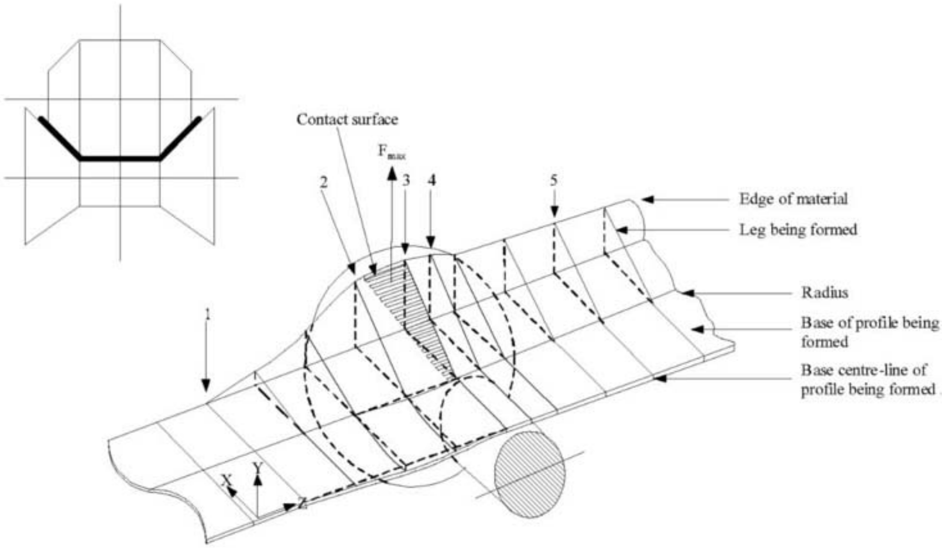

Figure 4: A typical forming pass and a cross section showing how the material behaves during forming.

3.2. Case study of cold roll forming product development in a knowledge environment

An enquiry was received from a customer within the construction industry, for three similar profiles, which were to be used in the fabrication of lightweight lattice beams, joists and trusses. The Steel lattice beams, joists and trusses were to be utilized in a wide variety of buildings where large clear spans could be easily achieved, such as schools, hotels, sports halls, superstores and industrial buildings. The customer needed a product that would show an excellent strength to weight ratio, as the lattice beams were required to be manufactured in depths ranging from 220mm - 3000mm and be able to span up to 38m depending on building type and application.

The initial profiles proposed by the customer detailed in figure 5, were analyzed to see if they could be manufactured, certain criteria such as physical size, shape and key features are checked along with the suitability of the material to cold roll form for the profiles. Once it was agreed that the profiles could be manufactured, the profiles were costed by the relevant departments and a quotation was put forward. Initial profile costs were considered acceptable, however tooling costs, were found to be too expensive for the project to be commercially viable. The tooling cost for the three profiles was £90,000. For the project to go ahead the customer required tooling costs to be no greater than £60,000. A review meeting was held with the customer to determine the critical requirements of the profiles and what features if any could be modified. Critical features identified included:

- Material properties, yield strength of 420 N/mm^2 minimum
- Structural properties, section modulus and I values, minimum values specified.
- The overall width of the component.
- Cost of tooling less than £60,000.

Considerable discussions were then held within the organization to determine how the profiles could be re-engineered to meet the customer specifications and reduce the tooling costs. As the profiles were very similar it was suggested that perhaps the same set of tooling could be used, with addition of spacers. The addition spacers could be used to lengthen or shorten the straight parts of the profile (within the organization this is referred to a modular/platform tooling). This was not possible with the current profile design as the forming rolls would have to be manufactured to suit the specific radii for each profile, however if the bend radii of each profile could be standardized, so there was one common size for the three profiles, there was a possibility the roll tooling could be modularized. This again was not straight forward, and certain material properties and associated design rules had to be considered.

The minimum bend radii allowed for the material specified is directly related to its thickness. The material specification S420 MC to BS EN 10149:2 1996 states minimum bend radius for the S420 MC grade material is a minimum of 1 times the material thickness, therefore the minimum bend radii for each profile would be 5.0, 6.0 and 8.0 mm respectively, however tightening the radii, to one of these dimensions would result in two physical changes that would need to be considered:

- An increase in the width of material required to produce the profiles, as the tighter the radius the more material is required to form the profile, thus product costs would increase.
- The tighter the radii, the more material is required, this results in an increase/decrease in the sectional properties of the profiles. (Dependent on shape and load direction)

Further study on the profiles structural properties was required to ensure that increasing the radii on the 5.0 and 6.0 mm profile did not alter the profiles structural properties beyond the specified limits. Results of the analysis carried out confirmed that the structural properties were acceptable.

To standardize the profiles tooling fully also required dimensional modifications, there were two options considered, firstly standardize the bottom forming rolls or standardize the top forming rolls. Standardizing the top forming rolls would have resulted, in additional set up time whereby all the rolls would have to be stripped off the rolling mill to change between one profile and the next. However standardizing the bottom rolls meant the majority of the bottom forming rolls could be left set on the mill and only the top forming rolls plus the addition or removal of spacers from the bottom.

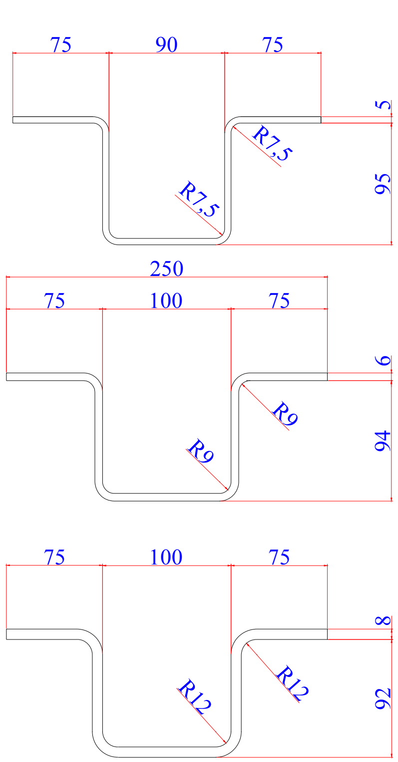

Figure 5: Initial profile designs put forward by the customer.

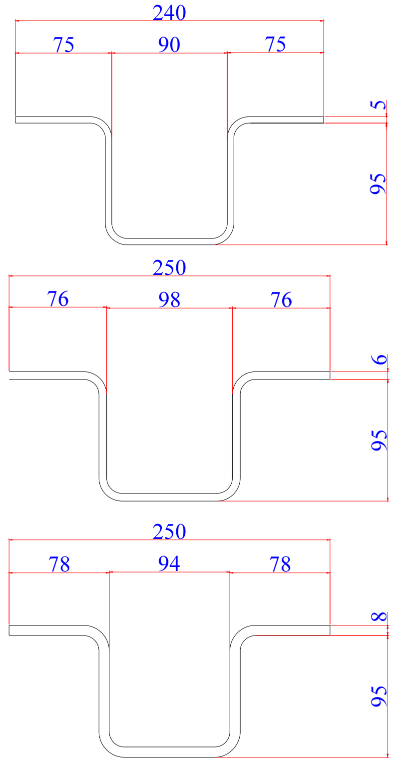

Figure 6: Modified profile designs to reduce tooling costs and improve productivity.

To standardize the bottom rolls required the height of the channel part of the profile being standardized, again consideration to the structural properties had to be considered, standardizing to the height of the shorter 8.0 mm profile (92 mm depth of channel), would have resulted in the 6.0 mm and 5.0 mm having less material and falling out of specifications for the structural properties required. Standardization of the bottom roll tool based on the deepest profile 5.0 mm (95.0 mm depth of channel), would result in an increase in material, an increase in strength and an increase in cost (due to the additional material), the proposal to standardize the depth of the profile to 95 mm plus material thickness was put forward to the customer along with the increase in product cost. The increase in product cost was considered as still being competitive and the customer agreed for tooling costs to be established based on the modified profiles as shown in figure 6.

Tool concept design was carried out based around the 5.0 mm profile, whereby top forming rolls would be dedicated to that profile, this was due to the reduced width (240 mm as opposed to 250 mm). The 6.0 mm profile tooling was designed utilizing the standardized bottom rolls and specific top forming rolls for the outer radii (18 mm) and spacer rolls to form the straight parts of the profile. The 8.0 mm profile was designed utilizing standard bottom forming rolls, top forming rolls specific to the outer radii (20 mm) and spacer rolls used in the design of the 6.0 mm top rolls.

Tooling costs, for the three profiles was reduced from £ 30,050 for each profile to £30,050 for the 5.0 mm profile, £15,500 for the 6.0 mm profile and £6500 for the 8.0 mm profile a total cost of £52,050. A saving of approximately £8000 compared to the customers budget and a saving of £37,950 compared to the tooling costs quoted for the original customer designed profiles. Further benefits were seen as a result of modularizing the tooling; lead time for delivery of tooling reduced from 18 weeks to 11 weeks, however this was countered by the additional design and development time of approximately 3 weeks. Further benefits were seen in production whereby set up times for each profile would have been in the region of 8 to 10 hours (setting time based on similar type profiles), to an average of 4.5 hours changing from 5 mm to 6 mm to 8 mm product, although initial set up of the first profile was 8-10 hours.

4. Conclusion

This paper presented a case to adopt Lean Manufacturing concept into product development where a major objective is to identify value and non-value added activities. In product development any activity that would result in customer requirements being met could be considered as a value added activity. Product development activities must be formalized and structured in such a way that any engineering decisions taken are based on proven knowledge and experience. Failure to apply proven knowledge and experience could result in product and process redesign, which would be seen as non-value added activities i.e. waste of valuable resource. As such there is a need for a formal new product development model as well as a knowledge-based system developed using the organization's knowledge and past experience. The authors consider that knowledge management in product development environment consists of four activities: identification, capture, formalize and present and utilization.

This research introduced the concept of Lean Product Development as the integration of engineering knowledge into a formalized product development process.

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Capitalization of knowledge from projects

Chaker DJAIZ[1], Davy MONTICOLO[2] and Nada MATTA[1]
[1]Tech-CICO laboratory,University of Technology UTT 10010 Troyes Cedex FRANCE
E-mail: {Chaker.Djaiz, Nada.Matta}@utt.fr
[2]SeT laboratory, University of Technology UTBM 90010 Belfort Cedex FRANCE
E-mail: Davy.Monticolo@utbm.fr

Abstract: The knowledge engineering offers a rational framework allowing a representation of knowledge obtained through the experiences. This technique found a great application in knowledge management and especially to capitalize knowledge. In fact, the rational representation of knowledge allows their exploitation and their re-use. It is a necessary condition to allow a re-use and a knowledge appropriation. The knowledge management must take into account this dimension, since its first concern is to make knowledge persistent, ready to be re-used. In this paper, we study the traces classifications of the design project achievements in order to have a knowledge aggregation and to thus provide a representation of handled knowledge, directives and competences organization as well as negotiation strategies and cooperative problems solving.

Keywords: Knowledge management, project memory, classifications, cooperative problem solving

1 Introduction

The knowledge engineering offers a rational framework allowing a representation of knowledge obtained through the experiments. This technique found a great application in knowledge management and especially to capitalize knowledge. In fact, the rational representation of knowledge allows their exploitation and their re-use. It is a necessary condition to allow a re-use and a knowledge appropriation. Behaviour laws provide strong semantics to observe as well as an argumentation of this behaviour, ready to be reproduced to solve new problems [Richard, 90]. The knowledge management must take into account this dimension of knowledge, since its first concern is to keep a persistent knowledge, ready to be re-used and adapted. In this paper, we present a form of knowledge management, keeping track and capitalization of project knowledge. This memorizing follows two essential steps: a project traceability [Bekhti & Matta, 03] and a knowledge capitalization. The traceability makes it possible to keep track of the episodical memory in which space-time associations of events are described [Karsenty, 96]. Project Memory is a form of this memory where cooperative problem solving and their context are represented. These events are a source for epistemic constructions, intended to build interpretations [Richard, 90] which can be represented in the semantic memory. Classifications of these tracks can be made. These classifications can be guided, either by a structure of representations and / or by typologies and generic knowledge.
We try to reproduce this step to represent the "collective" knowledge of organization. Indeed, the situations of problems solving arise through the projects. A traceability and a structuring of these projects "context and design rationale" provide a knowledge asset structured by situations problems. These various situations must then be analyzed to identify cooperation strategies as well as the knowledge handled by the organization. We will thus obtain a representation of the body "knowledge handled", directing actions "and competences of the organization" and behaviour laws “negotiation strategies and cooperative problem solving". Classifications can be based on similarities

of events and hierarchy aggregation of concepts (type of problems, conflicts …). Here, we present this latter type of classifications.

2 Project Knowledge

The realization of a project in a company implies several actors, if not other groups and companies. For example, in concurrent engineering, several teams of several companies and in several disciplines collaborate to carry out a project of design. The several teams are regarded as Co-partners who share the decision-makings during the realization of the project. This type of organization is in general dissolved at the end of the project [Matta et al., 02]. In this type of organization, the knowledge produced during the realization of the project has a collective dimension which is in general volatile. The documents produced in a project are not sufficient to keep track of this knowledge which even the head of project cannot explain. This dynamic character of knowledge is due to the cooperative problem solving where various ideas are confronted and with a cooperative definition of the produced solution. A project memory describes "the history of a project, the experience gained during the realization of a project" [Matta et al., 02]. The project memory contains knowledge regarding the context as well as the problem solving or design rationale. The structure of this memory can then be organized in two points, context and the design rationale.
The context represents:

- Organization of a project: the process and sequencing of the activities, actors implied with their role in the project and their competences;
- Working environment: methods, techniques and tools used, objectives, requirements and constraints, references, procedures qualities, standards, directives and rules.

The design rationale describes mainly [Buckinham Shum, 97]:

- Encountered problems: description and classification;
- Problem solving: proposed solutions, argumentations, decisions.

Often, there are interdependence relations among the various elements of a project memory. Through the analysis of these relations, it is possible to explicit and to make relevance of the knowledge used in the realization of the project. (C.f. Figure 1) presents an outline of this type of relations.

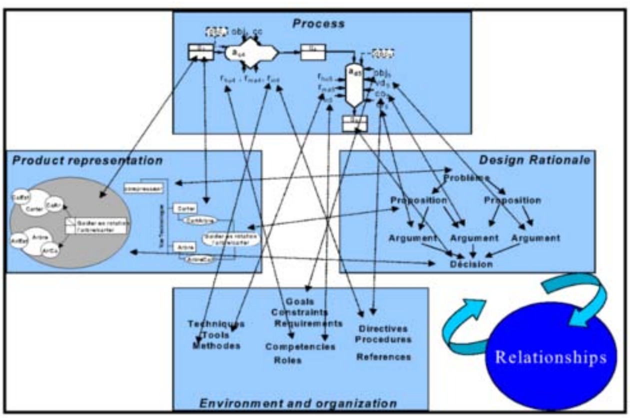

Figure 1: project memory organization

The traceability of this type of memory can be guided by design rationale studies [Karsenty, 96]. In the same way, work in knowledge management study techniques of traceability and definition of project memory [Bekhti, 03], [Matta et al, 00]. In this paper, we propose to study classification of project track as a mean to capitalize the organization knowledge.

3 Classification

Classification consists in gathering various objects (individuals) in subsets of objects (classes). It can be supervised where the classes are known, they have in general an associated semantics [Diday, 84], or not supervised where the classes are created via the objects structure, semantics associated with the classes are then more difficult to determine [Nack et al, 00]. In both cases, we need to define the concept of distance between two classes, which will be made by the means of criteria; these criteria of aggregation will be explained thereafter. Classification methods form part of the whole of the multidimensional descriptive methods, and their purpose is to clarify the structure of a whole (in our case, tracks of design projects). The main objective of the classification methods is to distribute the elements of a whole into groups, i.e. to establish a partition of this unit [Jain & Dubes, 88]. Several constraints in the form of assumptions are imposed and validated progressively, each group having to be the most homogeneous possible, and groups having to be the most different possible between them. The classification methods clarify the structure of an important data entity. It is then possible to classify a whole group of individuals who make it up, characterized by similarities criteria [Johnson, 67]. There are many methods of classification, and we only present, the most adequate for our work, [Benzecri, 73]. Hierarchical classification: Where hierarchy is obtained either by an agglomerative (upward) method, maybe by a divisive (or downward) method. In our case, we would like to establish causal relations (explicitly or implicitly) between the concepts of the preliminary project memories (the suggestions, discussed arguments, the competences, the nature of the task, initial knowledge on the problem, their kinds, the number of participants and their roles) and aggregations criteria which one will call dependent variables (the sociological criteria, psycho-cognitive, and relating to co-operative work), in order to define aggregation strategies, that can be summarized as follows:

Criteria **link** Concepts **to obtain** (Strategy R).

4 Traceability and capitalization process

Based, on classification methods, the traceability and capitalisation process (C.f. Figure 2), we propose, follows a number of steps and functionalities in order to allow firstly an enumeration of all the concepts, and secondly the use potential of regrouping mechanism of the project memory concepts. This allows facilitating the re-use, the interpretation and reading of knowledge produced and used in a design project. Traceability and capitalisation process follows then 4 steps: collection of the interaction, identification of concepts, characterization of criteria and regrouping.

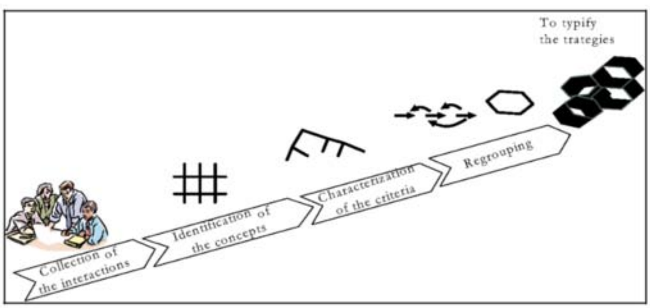

Figure 2: Process of Traceability and capitalisation

4.1 Collection of the interactions

The designer needs to learn lessons from the last projects in order to deal with new problems in their activities. Their needs are mainly focused on various elements for the last projects (like the problems dealt with in these projects, the decisions taken, the constraints, the arguments, the criteria, etc). So, we propose to collect all interactions as well related to decision making as to project context and organizations. These tracks can be analysed in the following steps of the traceability and capitalization process.

4.1.1 Identification of the concepts

It links two sub-phases which make it possible to support the concepts emerging during the meetings of projects, it consists, amongst other things, to give a micro view of the meetings of the project by peeling off all these elements (concepts) and by making the first separation, to be able to distinguish the aggregation thereafter:

1. Listing: listing all the concepts of the project of design, all participants' arguments or suggestions, as well as the decisions, to try thereafter to see possible separations: distinct problems, tasks not implying the same resources, participants not carrying out the same tasks, arguments…
2. Positioning: identifying the provisions of the concepts, those which can be gathered, for example, arguments with the suggestions corresponding to a participant…

4.2 Characterization of the criteria

It should be noted in this paragraph where we will present the criteria of aggregations of our process of classification, that several criteria can be released according to various aspects of the study of the cooperation and the negotiation in a project: sociological, psycho-cognitive and cooperative work.

4.2.1 Criteria from the sociological point of view

"Among the various types of communicative interactions which can be produced in situations of group, it is noted that the argumentative and explanatory interactions are particularly favourable with the Co-development " [Baker, 04], in addition to "the multiple relations which exist between the explanation and the argumentation" [Plantin, 96], "the first dimension (the explanation): corresponds to the degree of subdivision of the responsibilities for the realization for the tasks for the problem solving in the organizations " [Ducrot, 82]. In other words, it acts as the spontaneous distribution of the work of co-operative problem solving. These tasks relate on the one hand the problem to be solved, and on the other hand, the activity to cooperate with itself [Baker, 04], in and by the dialogue. When the responsibilities for the realization for these tasks are assumed spontaneously by the participants in a relatively stable way through the interaction, one will describes sociological criteria consequently depending on the task of the problem to solve parts played by the participants and of the arguments advanced [Conein et al., 92]. In these studies, we can propose, concept of organization of the tasks and argumentative and explanatory interactions. The argumentative criteria allow interpretation, vision and evolution of the suggestive arguments [Beaker, 04; Plantin, 90; Toulmin, 84; Ducrot, 82], the criteria of task can be distinguished on an organisational level throughout the evolution of the projects of design, knowing that a project of design forwards by three phases (Preparatory phase, Realization phase, Phase of finalization)

4.2.2 Criteria from the psycho-cognitive point of view

It was noted that research on distributed cognition, carried out in cognitive psychology these last decades, stressed the study of the acquisition of the procedures [Anderson, 83], instead of the development of "comprehension" on the conceptual level. In the case of certain types of problems, the performance can be dissociated from comprehension: the participants can solve successfully without thorough control of the concepts concerned. However, in the case of the production of certain types of exchanges ("epistemic"), like the explanation and the argumentation, it cannot have such dissociation: competence and performance as regards explanations coincident [Ohlsson, 96]. The psychology-cognitive sight

supports the individual aspect, which relates to participant and competence. We can distinguish from this study the criteria of the competence.

4.2.3 Criteria from cooperative work point of view

The study of the processes of collaboration must lie within a broader scope, that of a model of cooperative problem solving in and by the dialogue. A starting point impossible to circumvent is of course the "traditional" model of the individual problem solving [Darses, 96], who will consists on the six following phases: the search for a problem, development of a representation of the problem to be solved, the planning of the solving strategies, the generation of possible solutions, the checking of the solutions, the feed back in order to integrate knowledge (reorganization of knowledge). In the case of a team, these stages integrate other criteria such as the roles and their evolution (change and modification) [Hermann, 04], collaboration, interactions argumentative, conflicts, alliances of teams, negotiations. It should be noted that it is very probable that the cooperative problem solving in the projects of design, at a working group. A number of participative role one distinguished by PLETY [Plety, 96], relations between these roles will come to be added to support a number of creation from knowledge based on the negotiation such as relations of the complementarities type/alliance/ conflict. The roles can be the objects of the implicit or explicit negotiations. [Plety, 96] PLETY identified the four roles: Questioner, Verificator, independent and animator. We gathered these criteria to exploit them in the definition of the aggregation strategies.

4.3 Regrouping

Traceability allows keeping track of situations of cooperative problem solving and emphasizing characteristics of these situations. The capitalization of knowledge which we recommend is based on the similarity of these characteristics to make explicit the strategies learned by the organization through these projects. According to our state of the art (study on sociology, psychology-cognitive and cooperative work), we initially propose 5 types of strategy of regroupings which we go quoted below but thereafter we will explain two of 5 more clearly:

• **The regrouping strategy based on the carry out of the task:** Bonds appears between the concepts argument, resources, competences and product. It makes it possible to propose the realization of the tasks and the evolution of the design. These bonds request criteria like argumentative of change, dialectical and epistemic like competences of manufacture and task of project piloting (C.f. Figure, 4).

• **The regrouping strategy based on organization of the project:** Links related to the organization of the project can be distinguished. It concerns the suggestion of the attribution of role to task, based on competences.

We apply traceability and capitalization process on a windmill co-design project. We present in the next sections this application.

5 Windmill co-design

Each year a student team developed a windmill which is sent to an African country. Students have seven month to realize their project. They work in a concurrent engineering context. To follow their product development lifecycle they use a collaborative work plate form called ACSP (Atelier Cooperatif de Suivi de Projet in French). ACSP is a Web-based collaborative engineering environment, using the below described multi-domain and multi-viewpoint design model [Gomez et al, 2003]. This Web-based tool was developed as a CSCW environment, in order to organize and structure the collaborative activities of designers from anywhere in the world. We analyse interactions captured in the ACSP tool related to the wind mill co-design project. The collection and characterization of concepts allow defining a matrix (C.f. Figure 3). In this matrix, lines represent the data listed in the exchanges between participants (given characterized by concepts previously quoted in the structure memory of project). Columns represent the criteria and links between concepts. As we note on the traceability and capitalization process, thereafter, we will gather these concepts basing on this matrix and regrouping strategies. Before let us present some statements, extracted from one of the meetings held for the co-design of a wind mill. This example will help us to understand the aggregation process of the concepts.

Discussed problem: *the balancing of the rotor*
Statement 1: V.B.: "*we should analyze and re-examine the balancing of the rotor ourselves, and I should propose myself to do it, considering my knowledge in physics and mechanical design*".
Statement 2: T.M.: "*for time reasons I propose that we distribute the task and I believe we should call upon technical consulting firm for the final design of the rotor as well as the problem which relates to the generator to be used*".
Statement 3: C.S "*I agree with T.M., and I suggest that T.M. contacts the technical consulting firm but if a new manufacture of the rotor is required, V.B. should take care of it, considering his motivations and his materials*".
Figure 6, shows the result of concepts identification and characterization steps of wind mill co-design interactions.

Statement	Participant	Criteria	Incoming links		Mouve out links		
Project Wind mill design : EOLE GSC							
[illegible]							
Role1 project manager	TM	To take	Project / task				
[illegible]	TM	[illegible]	[illegible]				
Pb3/ task:Balancing rotor wind mill					Task 5		
Task 5: to analyze and re-examine the balancing of the rotor	VB	Specification/piloting	Pb3	competence1	Sugg5		
Sugg5: I should propose me to me, considering my some knowledge in physics and mechanical design?	VB (questioner)	Responsabilité	competence1				
Compétence1: Physics and mechanical design		To manufacture	sugg5, Pb3		Task6	Role2 (to take): to anlyze and to manufacture	
Resource: the rotor of wind mill	TM (questioner)	competence of manufactur	competence1/2		argument2	Task5	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sugg8:I propose that calls a technical firm of consulting for the final result of the rotor and the problem of the generator.	TM(questioner)	Quality	sugg7,task5	PB3	task7	Product4	PB4
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Arguement2: it it that us plane until maintenat measured 200 length for and poid of 7kg	GC(independant)	Pré-condition/ Arg of changing and epistémic	sugg9/ Resource	competence2	task10		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

Figure 3: matrix of characterization and identification concepts

We can note in this matrix different links between concepts, based on the corresponding criteria. These links allow identifying several partitions of the project knowledge. These partitions correspond to regrouping strategies we defined.

- **Example of carry out of the task partition:**

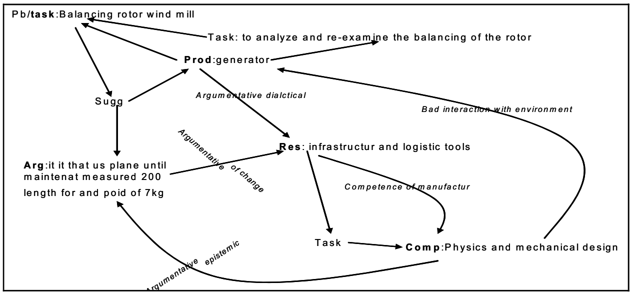

Figure 4: carry out of the task partition

We note links between task, argument, resource, competence and product. For instance, these links are characterized by manufacture and bad interaction with environment criteria. So we can gather these concepts on a carry out task partition.

6 Conclusion

The traceability of project knowledge is only one first stage for the representation of the cooperative problem solving. Indeed, tracks including concepts like participants, suggestions, competences, constraints, tasks, arguments, decisions are only representation of situations of cooperative problem solving. Aggregation using classifications of this information must be carried out in order to emphasize deep knowledge and to show the strategies of negotiation used to deal with environments. We use representation level recommended in knowledge engineering which proposes to make explicit the "why", "how" and the "what" of knowledge. We study the projection of this representation to express a knowledge emerging from of a collective activity like design projects. We presented in this paper our work on the definition of a method of aggregation based on a hierarchical classification. Therefore, we developed the different phases of this aggregation which is based on criteria and strategies. The criteria and the strategies were identified after a study of the project knowledge under three points of view: sociological, psycho-cognitive and cooperative work. This study made it possible to propose the main concepts and relations between these concepts to be considered a project memory. We plan to look further into this study and to determine other aggregation strategies. We illustrate strategies on an example extracted from a project track of design of a wind mill. We plan to validate the process of classification we defined, on the whole of these tracks and on other project tracks, for instance design of vehicle prototypes.

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Leading the Web in Concurrent Engineering
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Considerations of KMS implementation in Concurrent Engineering - economic perspectives

Billy T.W. YU, Peter K.C. LEE and W.M. TO
Business School, IPM, Macao

Abstract. The importance of knowledge management (KM) systems for organizational performance is now well recognized. Seeking to better utilize these systems in concurrent engineering (CE), this article focuses on the implementation considerations of KM systems from different economic perspectives. Specifically, the contribution of this paper is threefold. First, the paper reviews and compares various economic theories on the implementation of KM systems. Their respective ancestors are also identified. Second, based on some extant studies, some important considerations pertinent to the special features of KM are identified. Finally, we offer suggestions for more efficient handling of the identified CE deficiencies and the use of KM as a strategic tool to address those deficiencies

Keywords. Concurrent Engineering, Knowledge Management, Contingency theory, Transaction cost theory, Knowledge-based view, Evolutionary theory

Introduction

Due to inevitable interaction of marketing and manufacturing with design engineering in conflict and resolution, the integration of design and manufacturing operations is essential and becomes an increasingly important research area. In addition, many manufacturers outsource their design and manufacturing works and involve their suppliers in both design and manufacturing stages. As a result, the need for cross-functional and inter-organizational inputs necessitates consideration of how coordination and integration can be sustained across the inter-group and inter-firm relationship. When product development activities occur between firms, the issue of design and manufacturing integration is in fact less well developed. The notion of alliances and partnership development has been advocated which primarily focuses on considerations of how product development activities will be managed. In this connection, the initiative of a CE has to be a reality to minimize the conflict between design and manufacturing units.

CE is a systematic approach to the integrated, concurrent design of product and their related processes, including manufacture and support. [1] It is a useful and beneficial approach to reduce the development time and manufacturing cost, while simultaneously improving the quality of a product in order to better respond to the customer expectations. [2] It is intended to emphasize from the outset consideration of all elements of a product's life cycle from conception through disposal, including

quality, cost, schedule, and customer requirements. In most cases CE is envisioned as a modem application of systems engineering in an integrated computing environment.

To coordinate such complex interrelated activities, advanced information systems are necessary. Regarding creativity and day-to-day practice, cross-fertilization and handover of information, that is, knowledge creation and transfer are driven by cross-functional, simultaneous, and collaborative activities [3]. This article proposes a model of inter-firm mechanisms of KM in the context of CE. It is based on a review of literature on economic theories at the inter-firm level.

1. Economic Analysis of KM

Many organizations implement KM initiatives [4] and make use of KM as a strategic tool for its business development. Some of the first attempts at managing knowledge involved codifying knowledge into computer systems for future retrieval, regardless of the immediate usefulness. Some of these efforts were helpful but a good number of them consisted of merely data entry. Recently, KM initiatives focus more on enabling knowledge flow between those that need it. Researchers have drawn on a variety of disciplines and theories to help organizations understand how to better manage knowledge. Adopting a multiple economic perspectives, this paper considers factors affecting the creation, transfer and application of knowledge in business firms.

1.1. Contingency theory

The Contingency theory [5] argues that integration of value chain activities is achieved by a proper arrangement of highly integrated organizational structures, to support diversified activities, and some efficient tools, for knowledge work and conflict management. In this, the more closely integrated business processes among firms are, the greater the volume and frequency of the flow of information are. And, the greater the volume and frequency of information flow are, the greater is the firms' involvement to formalize procedures for information flow between them.

While the greater the degree of differentiation between the partner firms is and the higher the level of environmental uncertainty and change are, the more difficult it is to achieve organizational integration. Critical differentiation factors include relative power inequality, strategic goals, financial and legal independence between partners, management style, and formalization of processes and hierarchy of governance systems [6]. Shifting the focus to the inter-firm context highlights the high transaction costs that may be generated by opportunistic risk, as well as by the barriers to cross-boundary communication and coordination that are identified in contingency theory [7].

The way that knowledge is structured and the level of codification of the knowledge transferred in the venture can vary greatly. When collaborations require sharing significant amounts of tacit knowledge, the probability of knowledge transfer failure is high. This can lead to project failure and thus weaken trust relationships between partnering firms [6].

In the specialization in skills and technological capabilities for integration, the overlap in relevant knowledge domains between the members is a key factor. Knowledge exchange is difficult when this overlap is small. Here is the dilemma, specialist knowledge is potentially of greater strategic value but a high level of knowledge specialization among members will challenge the network coordination and

adaptation. Such specialization will impact the willingness of member firms to share specialist knowledge. The specificity of knowledge domains is determined largely by the level of task specialization of the firms in the network, a direct result of the breadth of task and firm independence [7].

1.2. Transaction cost theory

In the economic transaction cost model of inter-firm relations [8,9], firms in structuring their value chains have two options: they can either take on the risk of opportunistic behaviors by suppliers, or they can maintain costly and rigid specialized production activities inside their own legal boundaries.

In Williamson's description of the pure competitive exchanges, the scope of the relationship is limited to and defined by short term, opportunistic, contracts between buyer and seller agents/firms. And there is a high-cost and high-risk relationship due to the potential for opportunistic behaviour [8]. Therefore, the transaction costs are related to the need to negotiate, monitor and enforce the terms of contracts in the exchange. And investments on asset for such needs are a mean to reduce the potential of opportunistic behaviour[1]. Hill [10] provided a rationale for the emergence of stable collaboration. The growing complexity of technologies and production systems has greatly increased the bureaucratic costs of vertical integration. Under the expectation of continuous exchange relationships between firms, opportunistic behavior is greatly reduced. And hence, reducing the pull to vertical integration. And efficient selection mechanisms will tend to eliminate opportunistic actors and pick collaborative players [10, 11, 12]

There will always be trade off between flexible, but opportunistic, and relatively inflexible, but collaborative, vertical integration [13]. And business alliances will range from opportunistic to collaborative [14]. And a KM tool is the mean for such an efficient collaboration in the long run. As the asset specific investment required by the exchange relationship increases, the likelihood and cost of opportunism increases.

Regarding the KM systems, the scope and diversity of intra-network knowledge sharing are influenced by the network position [15, 16, 17] and absorptive capacity of the knowledge receivers [18, 17]. The transfer would also encounter greater knowledge barriers regarding differences in political, cultural and societal norms [19]. Consequently, the exchange of ideas and knowledge will be much more costly between culturally distant members. And assessing abilities of foreign employees and monitor their performance in the recipient country will generally incur higher information costs [20, 21].

1.3. Knowledge-based view

Nonaka's seminal works of the Knowledge-based view [22, 23] was primarily derived from the Resource-based view [24, 25] in the economic theory. Core competencies [26] often refer to members' specialist knowledge, which can be managed by technologies, rules, routines, and group-based problem-solving [27, 28]

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[1] Someone may argue that vertically integration is a solution to opportunistic behaviour. However, vertically integration somehow buds a dilemma. Internal 'hierarchies' (vertically integrated organizations) incur bureaucratic costs, which must be balanced against the transaction costs of the contractual or out-sourcing relationship.

The knowledge view of a firm enables us to look beyond the conventional lens of collaborative opportunities and competitive risks of doing business in an international setting [29]. The Knowledge-based view principally focuses on the underlying dynamics of knowledge exchange among the participating firms in a business exchange that can be advantageous to all parties. Different aspects of KM such as the access, acquisition, creation, contribution, dissemination, replacement and assessment were covered.

1.4. Evolutionary theory

Kogut and Zander in 1992 [30] expanded the idea of evolutionary theory of the firm in the context of the firm's knowledge in general. In 1993 [31] they summarised the factors affecting the growth of the firm. With the evolutionary perspective, firms compete on the basis of the superiority of their information and know-how, and their abilities to develop new knowledge by experiential learning. Productive knowledge defines a company's comparative advantage. The limiting factors on growth are not only the competitiveness of other firms nor the demand of the market, but more important is the extent to which their advantage can be replicated more quickly by themselves than through imitation by competitors, which agreed with the findings of Nelson and Winter in 1982 [12]. Thus, the efficiency in transferring knowledge relative to competitors dominates the superiority of the firm.

As for knowledge, Inkpen and Dinur [32] pointed out that the distinction between explicit and tacit knowledge should not be viewed as a dichotomy but as a spectrum with the two knowledge types [33]. And tacit knowledge is more difficult in transfer. Thus, firms specialized in the transfer of relatively tacit and idiosyncratic knowledge, which is with this broader evolutionary perspective, should have superior performance. Kogut and Zander in 1993 [31] suggested that, tacitness, or codifiability, is only one of the many dimensions for the efficiency in transfer. They further pointed out that some other dimensions are complexity, teachability, age of the technology, and the number of times transferred.

The KM Considerations and their respective antecedents, identified by the researchers as indicated, are ordered according to their importance for CE and they are listed in Table 1.

Table 1. KM Considerations and their respective antecedents

Theory	**Consideration**	**Antecedents**
Contingency theory [5]	Willingness to share	Specialization in skills [7]
	Volume and Frequency of information flow	Environmental uncertainty and change [6, 7]
	Amounts of tacit knowledge	
	Overlap in relevant knowledge domains	
Transaction costs theory [8, 10]	Knowledge sharing for collaboration	Need to negotiate, monitor and enforce the terms of these contracts [20,34]
	Employees learning	Cultural distance [19]
	The scope and diversity of intra-network knowledge sharing	Network position [15, 16, 17] Absorptive capacity [18]
Knowledge-based view [22, 23]	Access to existing knowledge and knowledge creation	Motivations for collaboration [35,36]
	Knowledge acquisition and contribution patterns	Mutuality and reciprocity in knowledge exchanges [37]
	Knowledge acquisition from parents	Absorptive capacity of the recipients [38]
	Knowledge development, dissemination and replaces	Institutional arrangements and Preferred channels for knowledge transfer [39, 40]
	Tacitness of knowledge	Characteristics and process of knowledge transferred [41, 42, 43]
	Innovation	Moderating role of the industry environment [44]
	Assessment of knowledge acquisition goals	Necessity of goal congruence among parent-firms [45]
	Learning - International Joint Venture	Parental engagement and oversight [46,47]
Evolutionary theory [12]	Relative efficiency in transferring knowledge	Knowledge characteristics [31]

2. The CE challenges

Executives in firms face the difficult tasks of implementing KM in CE, especially in the current high-pressure (intensely competitive business) environment. Decision-making is particularly difficult when team members are geographically dispersed. Especially when they come from a broad range of cultures and disciplines, and interact for a relatively short period of time [48].

Penrose [24] constantly contend that creativity is the most strategic and limited of all the organization's resources. However, a number of researchers, e.g., Machado in 2003 [49], Umemoto in 2004 [50] and Spender in 2006 [51], have pointed out that studies on concurrent engineering have focused on efficiency but only a few discussions were conducted for its provision for organizational creativity. They argued that uncertainty and diversity necessitate concurrency which produces benefits of creativity as well as efficiency, which in turn realizes product integrity. Actually, here it comes the catch. Creativity and innovation concern the process of creating and applying new knowledge. As such they are at the very heart of KM. In 1998, Gurteen [52] argued that our creativity is 'blocked' in a variety ways. It seeds form the deep-seated beliefs of an individual or an organization thinking about the world.

And, generally speaking in KM, the dynamics of knowledge interplays among the parties. This notion always concedes CE in a way that it harmonizes the chaotic and complex conditions [52]. This is accomplished by efficiency and creativity effects that CE's concurrency produces [29] [50]; and the basic KM activities facilitate organizational innovation [53].

In terms of innovation, knowledge accumulation can influence the specifications of a co-development project, and sometimes, suppliers would modify their manufacturing settings or even devise new way of making decision to match with their buyer's new requirement [54]. But regarding creativity of CE, collaborative activities among professionals from many different knowledge domains may emerge problems. In such diverse backgrounds and strategically ambiguous goals from the top, or from the mother company, uncertainty should be tolerated [50].

3. Considerations of KM implementation in CE

KM systems are used to reduce barriers between partnering firms or to render enhancement in a way that it compromises the limitation of CE. Last section on the CE challenges has detailed them. And, the section on economic theories has stressed the consideration in implementing KM in various aspects and their respective antecedents were identified. To cope with the specific CE requirements as defined in the CE challenges, particular attentions should be paid.

Table 2. KM Considerations for difficulties that CE may encounter

Difficulties	**Researchers**	**Solution provided by KMS and the considerations**	**Researchers**
Efficiency but little creativity	Machado [49], Umemoto [50] and Spender [51]	Activities facilitate organizational innovation	Spek [53] and Eunni [29]
Broad range of cultures and disciplines	Umemoto [50] and Coman [48]	Willingness to share Overlap in relevant knowledge domains Employees learning	Moffat [7] Lam [6] Hennart [19]
Interact within a short period of time	Coman [48]	Volume and Frequency of information flow	Lam [6] and Moffat [7]
Deep-seated beliefs	Gurteen [52]	Knowledge acquisition Relative efficiency in transferring knowledge	Lyles [38] Kogut [31]
Chaotic and complex conditions	Gurteen [52]	Dynamics of knowledge interplays among the parties Volume and Frequency of information flow	Gurteen [52] Lam [6] and Moffat [7]
Specifications of a co-development project	Appleyard [54]	Knowledge sharing for collaboration The scope	Jones [20] and Cho [34] Tsai [17]

A summery of considerations to be aware of for particular potential difficulties that CE may encounter was exhibited in Table 2. The first column summarized the potential difficulties identified in the last session. Each item in the column was actually an independent variable when we design a KMS, and thus it could be treated as the antecedent for the consideration. With the aids of Table 1, the third column was created. For examples, when team members are from a broad range of cultures and disciplines, the employee learning should be carefully considered so as to narrow the disparity in opinions and hence a smooth progress. For Interact within a short period of time, Volume and Frequency of information flow should be carefully considered in the design of the KMS. For uncertainty in goals and mission in the co-development projects, knowledge sharing for collaboration and the scope should be carefully considered to facilitate the communication for a common goal development. The rest of the table explains itself likewise.

When CE is within a hierarchical power, as a special case, parental engagement and oversight shall help subsidiary learning; while the CE is a business partner relationship, the need to negotiate shall shape the collaboration and knowledge sharing, and the mutuality and reciprocity in knowledge shall outline the knowledge acquisition and contribution patterns.

4. Conclusions

This research is limited to the economic perspectives. The implementation of KM systems should also take into account the KM theories and the practical operations. But since the later ones have been well researched in the computer literatures, this paper focuses on the economic aspects, examining nothing about the technology that underlies the firm's production function or the processes that lead to maximizing decisions. Reader interested in the technological aspects other than that described in this paper are suggested to follow Chen's review work in 2006 [55].

It is often thought that creativity is a serious analytical task limited to certain disciplines such as R&D. It is also thought that cultural and goal communications are difficult for parent companies. These would have been cracked in CE, especially when it is with KM, which basically encourages creativity as one of its main purposes, and the many more implementation considerations with respect to previous researches. This paper reviews on multiple economic theories and their implications to the implementation of KM. Based on the review and discussion performed, we offer a number of suggestions on the considerations in various conditions and settings in CE.

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Global Standardization and CE

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Leading the Web in Concurrent Engineering
P. Ghodous et al. (Eds.)
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The Ubiquitous Factory of the Future based on STEP-NC

Van Khai Nguyen (HES-Ge, CADCAMation), Alain Brail (AIRBUS France SAS)

The survival of traditional factories (especially manufacturing SMEs) within the global economy, with productivity pressures, scarce resources and capabilities, relies on their ability to embrace new ideas and new organizational forms and to imagine new ways of delivering value to customers, new approaches to collaborating with suppliers. Eliminating the barriers to make possible the new paradigm **"design anywhere, build anywhere"** is a crucial challenge for manufacturing industry to gain competitiveness in the new emerging markets, and to better cooperate (and not only to compete) with low-wage countries. Information Technology plays a strategic role and the unbundling of modern global enterprise depends on the connection of machinery over the internet and the ubiquitous behaviour of machines-tools. Full interoperability towards digital factory and extended manufacturing process opens up new perspectives of collaboration between OEM firms and their suppliers. **STEP-NC is being identified as the main enabling "IT bus" for manufacturing industry and is driving the opportunity for change towards the targets of digital, adaptive, networking, and knowledge-based manufacturing for the factory of the future.** The higher information level provided by STEP-NC allows the development of a new breed of intelligent (holonic) controllers, capable to be self-adaptive and autonomous to meet the manufacturing requirements to deliver the final part as requested by the customer. This paper starts to describe the results achieved within the previous projects for the definition of the STEP-NC feature-based data model and standard and envisions new crucial developments for a breakthrough vertically integrated paradigm of the whole manufacturing process.

Leading the Web in Concurrent Engineering
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Intellectual property protection in Concurrent Engineering domains

Lionel Antegnard, Dr. Harald Liese and Dr. Josip Stjepandic
Regional Manager France, PROSTEP AG
Manager CA Applications, PROSTEP AG
Head of Competence Center CA Technology, PROSTEP AG

Abstract: In the age of the globalism the data product definition exchange becomes between the different parties in the creation of value chain, a natural form of business communication. The status of the Knowledge Based Engineering application, the problems with the protection of the Intellectual Property and exemplarily solutions for their protection are explained in the available contribution.

Keywords: Intellectual Property Protection, Knowledge Based Engineering, Supply Chain, Competence Network

Introduction

Wide ranges of the producing industry have been using the three-dimensional CAD systems and adapting their usage for years ago. The continuous optimization includes both the integration of the CAD data in the whole process chain and the application of new functionalities of modern CAD systems. The Knowledge Based Engineering becomes with the new CAD modules to a special meaning [1]. Hereby it will be possible to along-store the design knowledge to substantial extent with the CAD models and to accelerate thus the product development [2] crucially. The individual KBE methods is represented in the fig. 1.

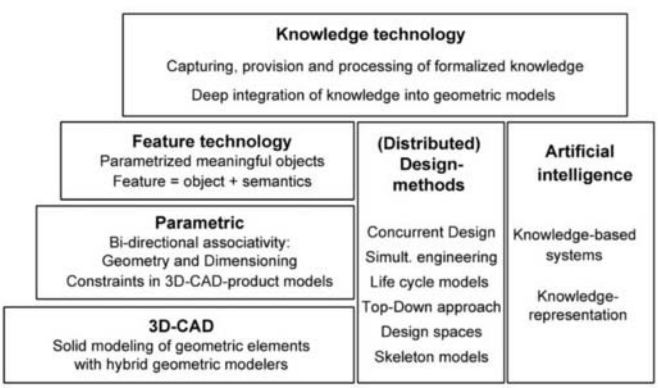

Figure 1. Usage of Knowledge technology in 3D CAD systems

The chances, which this technology offers, are generally highly estimated. However one is regularly confronted before their introduction with the potential risks. Therefore the first questions which arise in practical handling of the Knowledge Based Engineering are, with which methods and procedures are we able to protect own intellectual property against not authorized application and potential abuse. So due to the apparent risks and the missing solutions, then conventional methods are used further instead of apply and develop dedicated Knowledge Based Engineering methods and solutions.

Problem definition

In many industries (automotives, aerospace) the product development takes place at present usually through global development partnerships. OEMs accomplish the development of new product in variants multiplicity at several locations in several countries. Furtermore a variable number of external services providers and suppliers takes part in individual projects. These are supported for their part even by a variable supplier pyramid. In this way the products development and production are realised through a complex supplier network and the OEM can never know exactly which enterprise at which place of which part of the development is involved. The relations in this network is temporary and applies only in principle to the current project. The project partner from today can quite become the sharpest competitor from tomorrow.

The IT infrastructure is adapted constantly to this constellation. Various and global data logistics are available for the exchange of 3D data especially for the automobile industry. The safety mechanisms (access protection, encryption etc.) are already completely implemented on the side of the data producers. By the increased employment of 3D data the exchange volume rises continuously. In this surrounding field the CAD data including all of their components can be seen copied and processed further by a multiplicity of persons from different organizations. Under the acceptance that no limits were set to the distribution of the design knowledge, the importance of this know-how protection become an evidence as the fact that this knowledge leak have to be avoid. In order to defeat this by any means acceptable, two possibilities could be applied: to completely begin the suitable procedures of the Intellectual Property Protection or to postpone the use of new technologies.

But the difficulty results in the the different interest situation of the parties involved in product development. The customer (e.g. the OEM) refers the parts and/or explicit services of its suppliers and/or external services providers, is interested however in principle in their whole technology and know-how. Thus by the suppliers it was often claimed that of them drafts provided during the concept competition context by the OEM were later continued to give to their competitors. On the other hand the suppliers are always interested that in the context of a project the developments achieved are reused with the next project e.g. with another OEM. So the first OEM as client and new development financer sees in fact the danger, that he is supported over detours its competitor. This area of conflict is existing since longer and has got an additional explosiveness by the employment of the KBE modules. It was never so simply to approach to the missing know-how by the data larceny. By the surface covering introduction of the CAD system CATIA V5, which contains several KBE modules under the generic term Knowledgeware and which are used by european automobile and aircraft industry, it is also became clear by their top management, how

risky it is through an uncontrolled spreading to distribute its design knowledge stored within CAD data.

Different interest situation and consequences

The increasing number of plagiarisms, which inundate certain markets, suggests an intensive, not intended discharge of the statements during the development process. With the risks estimation of the loss of Intellectual Property both enterprises themselves and independent organizations are concerned. Aberdeen Group surveyed 88 companies [3] to determine the degree to which best-in-class organizations are using security solutions to address the risk of the insider threat (insider are the supplier and service provider too). The results uncovered that the majority of respondents have yet to implement technology to address insider threats. Only the best in class companies reported the decreasing security events. Otherwise on the industry norm and laggard companies significant increase in security events occur yet.

To that extent a high action need exists, with both OEMs and suppliers. The OEM has large interest to place its CAD data selectively and temporarily (project-related) available to its suppliers and services providers. Its CAD data, which can contain e.g. the conception of its vehicle, should in the best way expire to a certain project milestone. The extension of this time window in the availability of the CAD data could give the possibility to the potential data thieves of copying the plagiarism quasi parallely or at least time near without own developing costs.

The supplier, which feels by the obligation to supply native CAD data to its OEM is substantial under pressure and he is again anxious to supply only a minimum required extent of CAD data that its documentation obligation fulfilled. The simplest stage represents enveloping geometry as BREP geometry. If this is not sufficient, then BREP geometry is taken of the whole product. Further stages would be the feature model (without the parametric), the fully parametric model (incl. the adapter models). At the end of this scale then complete model stands inclusively KBE elements, as it was provided by the producer.

Alone the length of this enumerating´s documents shows how delicate can be this CAD model´s reduction. What will be amplified when it concerns assemblies, which possibly consists both of new designed or redesigned/reused parts. Therefore the supplier is held sometimes to proceed selectively in the reduction of CAD model and to remove only critical contents. Here not only the efficient software solutions have to be selected, but the exact data exchange strategy must be defined by the supplier before project´s start.

From this interest situation result model simplification and digital rights management (DRM) are the most important action fields (Fig 2). The DRM lies in focus of OEM, as it was already admitted for other applications (e.g. content management). The supplier sees itself best protected by the physical model simplification, which does not permit interpretation clearance.

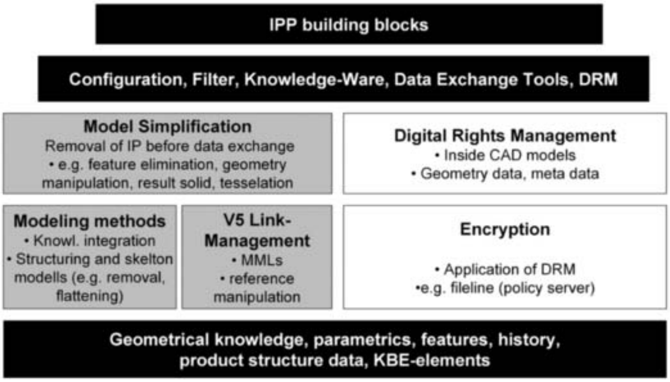

Figure 2. IPP - Structuring in methodical building blocks

IPP Methods

The problem of the Intellectual Property Protection is pursued parallel to the advancement of the CAD systems. The security is critically affected though systematic embedded knowledge elements (Fig. 1) into CAD application too. Both OEM´s [4] and suppliers trigger this process. Also the competence networks like the Supplier Collaboration Center and ProSTEP iViP Association in Germany are concerned themselves by requirements harmonization and methods development [5] [6] so they set up with industrial representing and software provider dedicated workshops on this thematics. One of this IPP Workshops participant expressed itself as follows:
"To preserve our jobs it is urgently require to protect innovations from engineers heads as mental capital. If boundary conditions like global patents penetration and creativities attention are missing, then everyone must itself defend against the knowledge predatory exploitation."
Fig 3 shows those at present for the automotives industry relevant methods.

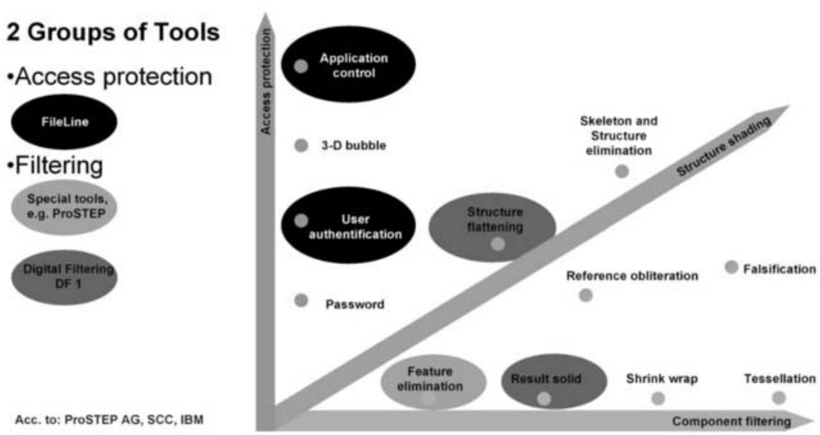

Figure 3. Solution concept – CATIA V5 additional tools [4]

The methods differ according to the basis procedures: the component filtering and the access restriction. The structure shading connects the two basis procedures. The represented methods show completely different aspects. While methods in R & D are based on CAD data access restriction, the component filtering and the product structure shading methods are used meanwhile isolated in production.

Use case OEM – supplier relationship

This section represents software solutions developed by PROSTEP in the last years dedicated for Intellectual Property Protection and in use at present by industrial customers. The simplest form of the IPP represents the "Knowledge Editor". This solution concerns a CAD CATIA V5 application development dedicated to manage the construction knowledge into the CAD models (Fig 4).

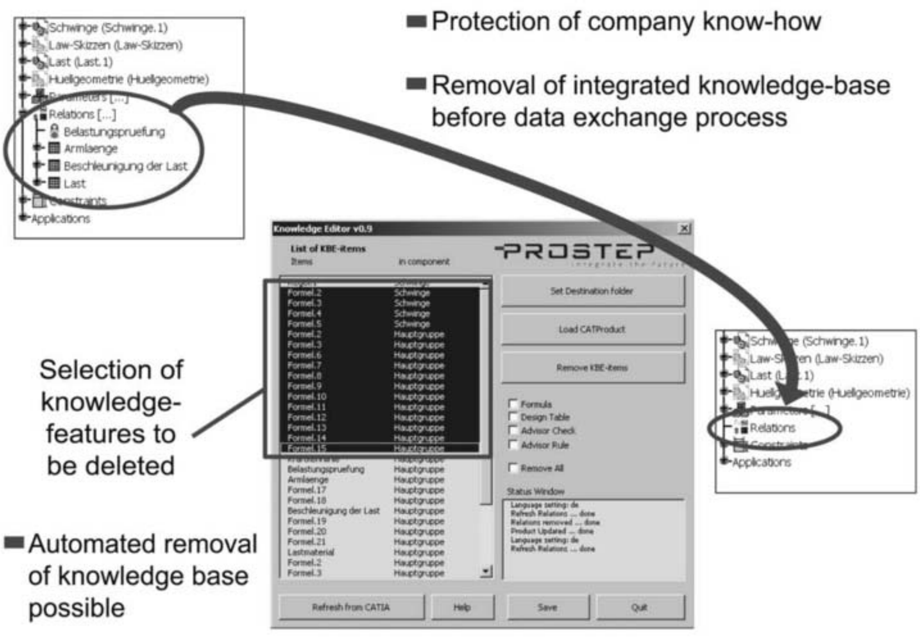

Figure 4. Example: PROSTEP Knowledge Editor

The Knowledge Editor is an additional module with an interactive user interface, which can be called before the data dispatching. It checks if protection worthy elements are located in CAD model contents and eventually removes them. The delete operations are accomplished at a work copy of the original models. The knowledgeware objects can be selected according to various criteria. The data producer keeps visual control of the knowledge stored in the CAD model. The special advantage: One does not regard the delete operation to the result models. The receiver cannot recognize through the

models received whether these were prepared and simplified before to be dispatched. They look in such a way, as if they would have been generated without usage of KBE modules application.

The interactive Knowledge Editor is suitable in-special for treatment of single parts and smaller assemblies. With larger, multi-level assemblies interactive editing is recommended not much. The response times do not become acceptable any longer and it are missing ever more the overview of the effects of individual delete operations on other parts and objects. Furthermore the link management is very much complicated, if the adapter parts must be removed in one hand and in the same time exchanged with the PDM data (Fig. 5). In this case the definition of an automated method is recommended, in order to filter CAD models contents and to adapt the product structure. The most important condition for this is the definition and application of a CAD design method according to the appropriate top down approach in order to generate the design data. Thus guaranteed that the adapter models - which contain always considerable design knowledge without to be crucial for the external form of the product - can be removed and at the same time to have the ability to avoid the "ghost links". Due to the higher storage requirement and longer running times this method is recommended to be launched in batch. The Knowledge Editor runs likewise in batch and is steered by the pre-defined option files. For adaptation of the PDM data to the new assembly structure the tool OpenPDM is developed by PROSTEP, in order to supports also the check-out actions from the PDM system.

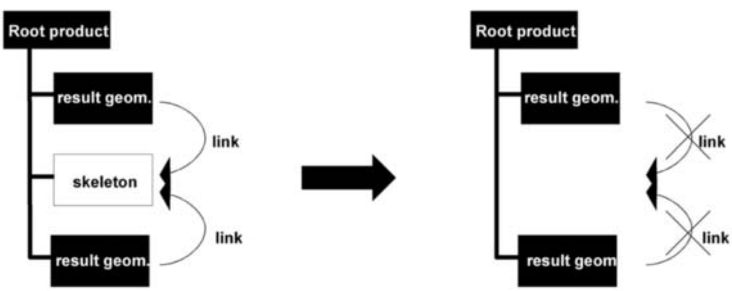

Figure 5. Example: product structure simplification

By the combination of model simplification and product structure shading arises a multi-level process as shown in Fig 6. In order to co-ordinate the individual steps and to synchronise the individual operations, the product OpenDXM is used by PROSTEP, which is also used as front end for the user. Thus a continuous process results, without user interaction requirements. Its assistance is limited to start the data exchange process and to check the logs files, in order to validate that all individual operations were correctly finished. Thus the Intellectual Property Protection is reduced to a process step in the data exchange chain.

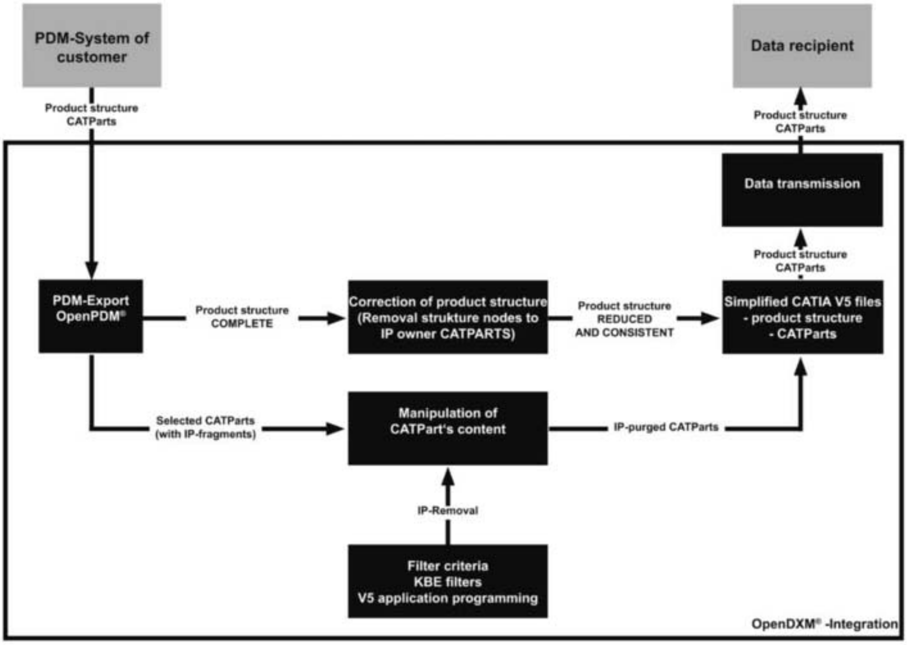

Figure 6. Example: Integration of IPP in data exchange process

Conclusions and Outlook

In this contribution are represented the problems, the solutions as well as the productive software solutions for the Intellectual Property Protection. Outgoing from the various risks and challenges the Intellectual Property Protection requires a bundle of suitable organizational and technical measures. On the own position in the supply chain and the interest situation depends, which from many technical measures must be used in priority. The ability to successfully resolve these issues includes the right priorities, the well established actions, the use of enabling technologies and the measure of performance.

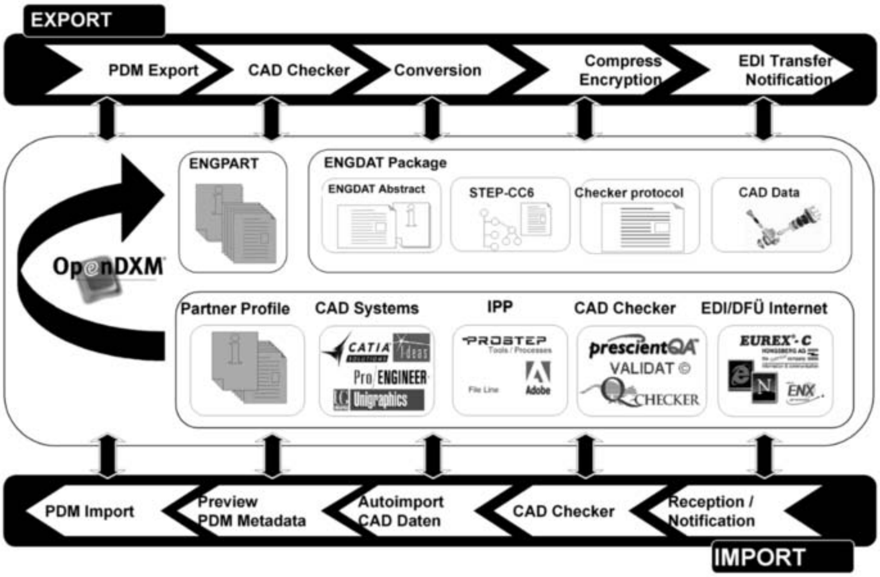

Figure 7. Example: OpenDXM process chain using IPP

On basis of prominent CAD- and PDM systems building batch applications, methods and solutions advancement to the Intellectual Property Protection will become toward of scalable and let them insert into existing full automated CAD and PDM process chain. Such a process chain supported by the OpenDXM is in Fig. 7 represented. The adjustment of one such process chain will have to be accomplished as personnel-intensive activity by a separate module (IP monitor). By this technology each enterprise acting in the supply chain will be able situation-dependently to protect its Intellectual Property, without disturbing regulated data flow.

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Comparison of data models for plant lifecycle information management

Pekka Siltanen[a], Antti Pärnänen
VTT, Finland

Abstract. Several data models have been defined for enabling information interoperability during the process plant life cycle. The data models differ in details and their scopes are different, making it difficult to compare and evaluate them. While the importance of using commonly agreed standard data models has widely been accepted, the diversity of the models hinders companies from choosing between them when implementing e.g. data warehouses. In many cases this leads to implementing in-house, non-standard models. In this paper, criteria for evaluating and comparing data models are introduced. Five data models developed by international or national organizations are introduced and compared, based on the criteria.

Keywords. Plant modeling, interoperability, STEP, IFC, ISO 15926, AEX

Introduction

During the life cycle of process plant, a huge number of information is exchanged. The information pieces often depend on each other or overlap. Thus, application integration methodologies that automate information exchange without losing information dependencies are needed. However, the diversity of the standard data models hinders companies of choosing between them when implementing e.g. data warehouses. In many cases this leads to implementing in-house, non-standard models that slows down implementation of the international standards.

In this paper we try to define criteria for evaluating the data models and compare some data model standards that are suggested for improving interoperability in process industry. The purpose of the paper is to ease the difficulties the process industry companies are facing while trying to follow the development of the different standards. The scope of this paper is in *technical information*, as distinct from the business information used in business processes or information related to chemical processes. Also, we set the scope in this paper such that business messages, such as *request for quote,* are outside of the scope of this document.

[a] Corresponding Author: Pekka Siltanen, P.O.Box 1000, FI-02044 VTT, Finland; E-mail: pekka.siltanen@vtt.fi

1. Requirements for the Data Models

Requirements for a data model used in information exchange derive from business processes. As an example of process industry requirements, Figure 1 describes an upper level process description of a paper mill life cycle. Between each process phase information is exchanged.

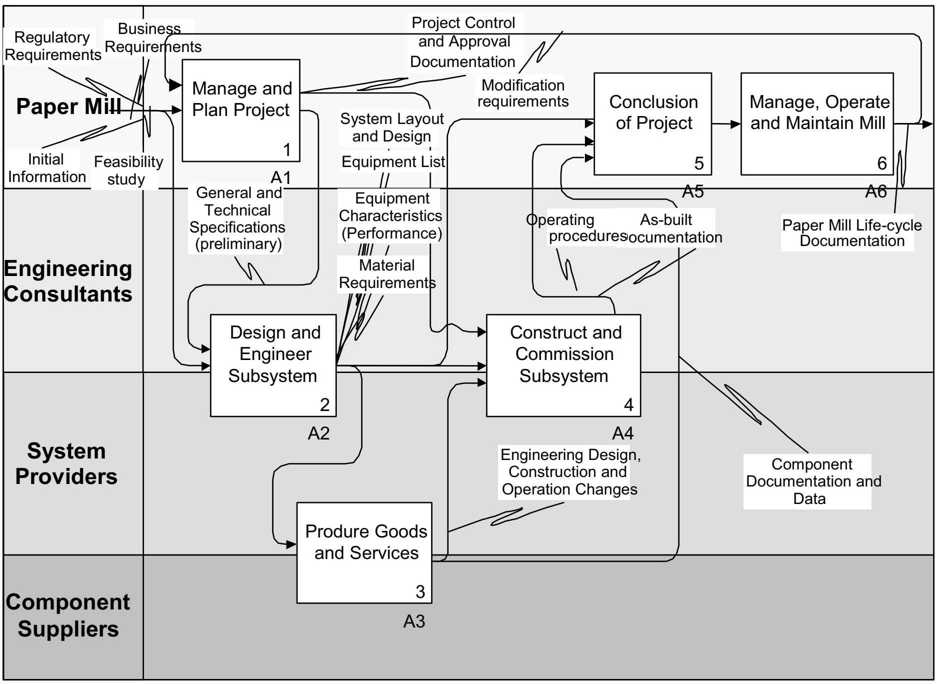

Figure 1. Information flows during paper mill life cycle (modified from [1])

In this paper, the requirements are divided into the following categories (partly derived from [2]):

- Business requirements
  These are requirements that result from different business needs for the creation and use of information.
- Technical requirements
  These are requirements that result from different technical environments in which information is created and used.
- Usability requirements
  These are requirements that result from the model implementers' ability to understand and implement the definitions.

1.1. Business requirements

The data model should enable sharing and exchanging technical information, but it should also be widely accepted and used in the industry. The main requirements considered here are: *Coverage of technical disciplines:* the data model should cover al the technical disciplines needed during the plant life cycle; *Information content*: the data model should be able to be used for exchanging information currently presented in documents (such as block diagrams, process flow diagrams, process and instrument diagrams, operating information etc.); *Status of model specifications:* the specifications should be maintained and actively developed, *Speed of adoption*: there should be enough practical support to enable rapid implementation, and *Internationality:* specification should be international.

1.2. Technical requirements

These requirements relate to the need to apply different technologies to different business scenarios, i.e. information is stored and used in different applications: *Data exchange*: there should be an open exchange format (preferably XML based) that covers all the aspects defined in the data model; *Data integration*: there should be service interface description that covers all the aspects of the defined in the data model,

1.3. Usability requirements

These requirements relate to the easiness of acceptance and implementation of the specifications. The following requirements have been identified (partly derived from [3]): *Understandability:* the data model concepts should be based on the objects in the everyday life and the definition should be clear and unambiguous; *Implementability*: information systems and data integrations based on the data model should be easy to implement using existing technologies; *Flexibility*: the model should be flexible when business or technical requirements change.

2. Introduction of the Data Models

In this section five data models developed for modeling technical information in capital facilities industry are introduced. The five data models were selected among the most well known definitions by well established organizations.

2.1. ISO 10303-227: Plant spatial configuration

ISO 10303-227 [4] is an international standard for the exchange of spatial configuration information of process plants among all project contributors. The spatial configuration information focuses on the shape and spatial arrangement of the components of the plant piping systems. Components of the plant piping system include pipes, fittings, pipe supports, valves, in-line equipment, and in-line instruments. The standard is mostly used in ship building industry.

The scope of ISO 10303-227 includes e.g. plant items, site characterization, change information, geometry and connections between plant items.

As ISO 10303-227 is part of the STEP family of standards [5], a large number of methodologies are defined in the other parts of the standard family, e.g. modeling language EXPRESS [6], connection to other STEP modules, exchange format, data access interfaces etc.

2.1.1. ISO 10303-221: Functional data and their schematic representation for process plant

ISO 10303-221 [7] concerns *the functional and physical aspects of plant items*. This includes normal design documents, e.g., P&IDs and data sheets. Development of the standard was suspended for years, and it is currently being harmonized with ISO-15926.

The principal focus of 10303-221 is the piping and instrumentation diagram (P&ID) and property information about the plant items.

The scope of ISO 10303-221 includes e.g. plant system and equipment identification, connectivity, classification, definition of standard functional and physical classes, properties, materials and project data.

2.2. IFC

The scope defined by the IAI (International Alliance for Interoperability) for the IFC Object Model [8] is "enabling interoperability between AEC/FM applications from different software vendors". Its original target was file exchange, but some projects such as SABLE [9], have implemented model server based approach.

The aim of the IFC Model is to be able to support the exchange and sharing of information throughout the construction project lifecycle.

The scope of IFC covers building geometry, topology, spatial structure, building elements and relationships between building elements. IFC also covers building equipments and furniture, as well as people, organizations and project data. The *domain layer* defined in IFC contains specialized concepts, such as footing, pile, boilers, chillers and so on.

2.3. ISO 15926

ISO 15926 is an International Standard for the representation of life-cycle information for process plants, including oil and gas production facility [10].

The representation of lifecycle information is specified by a generic, conceptual data model [11] that is suitable as the basis for implementation in a shared database or data warehouse. The data model is designed to be used in conjunction with reference data library [12] that defines discipline specific object classes and will be continuously updated.

ISO 15926 is targeted towards defining data model for data warehouse applications, and it also defines data exchange methods [13].

The scope of ISO 15926 includes all plant life cycle phases from conceptual design operation and maintenance. Object classes defined in the reference data library [12] include e.g.: piping, valves, electrical, instrumentation, heat transfer and also organizations, activities and document types.

2.4. AEX

The AEX project [14] is developing data exchange specifications for automating the design, procurement, delivery, operation and maintenance of engineered equipment. Phase 1 of the project delivered XML specifications for exchanging data sheets. Phase 2 is extending this work to support additional types of equipment and is developing pilot implementations with participating software and equipment suppliers.

The scope of activities to be supported by AEX covers process from equipment data development to data collection and operation and maintenance documentation. Equipment classes defined in the first phase of AEX-project include e.g. heat exchangers, rotating equipments and accessories, storage vessels, pipes, instrumentation, control devices and accessories.

3. Comparison

Reason for so many applicable standards arises partially from the fact that process industry covers such a wide range of industrial disciplines and partially from the fact that there has not been sufficient consensus of the solutions.

Table 1 summarizes the comparison of the business requirements. When information content and disciplines covered are compared, some differences are noticed. ISO 15926 and AEX are the only specifications that are planned to cover all the process industry needs, while their specifications are still incomplete.

All the ISO standards have developed very slowly, with the possible exception of ISO 15926 that seems to be actively developed. IFC and partially also AEX seem to have wider implementer base than ISO 15926, which is essentially result of a small specification team.

	AP227	*AP221*	*IFC*	*ISO 15926*	*AEX*
Information sharing between disciplines	Mostly piping, HVAC etc. No automation etc.	Mostly piping and related. No automation etc.	Mostly construction disciplines.	Wide coverage of disciplines in RDL.	Wide coverage of disciplines planned.
Information content	Covers subset of process industry needs.	Covers subset of process industry needs	Intersects with process industry needs.	Planned to cover all the needs.	Planned to cover all the needs.
Status of model specifications	Edition. 2 – Draft International Standard (2003)	Draft International Standard (2005)	IFC R2X is an IAI standard. ISO/PAS 16739 (2005)	15926-2 international standard 2003.	Release 1.0 2004.
Speed of adoption	Slow	Activated again 2005.	Slow but accelerating	Not yet known, high interest	Not yet known, high interest
Internationality	International	International	International	European	American

Table 1. Comparison of the data models regarding the business requirements

The technical requirements are summarized in Table 2. The standards are mostly based on EXPRESS models and therefore they also use the exchange file format defined in ISO 10303-21 [15] that is an ASCII based file format not gained any support outside the STEP community. AEX on the other hand defines only XML schemas.

Application programming interfaces are not specified in all of the standards compared. STEP standards (AP227 and AP221) can use STEP standards data access

interface [16] and ISO 15926 has defined its own Façade interface [13]. IFC itself does not have any programming interface, but Sable project [9] has defined an API specification on top of IFC. AEX specifies only data exchange formats and has not yet defined any programming interfaces.

rototype stage.	AP227	AP221	IFC	ISO 15926	AEX
Data exchange	Exchange file formats: ISO 10303-21 ISO 10303-28 (XML)	Exchange file formats: ISO 10303-21 ISO 10303-28 (XML)	Exchange file formats: ISO 10303-21 ISO 10303-28 (XML) , IFCXML	ISO 15926-7 XML/OWL templates	XML format based on AEX schemas.
Data access	STEP standard data access interface (ISO 10303-22)	STEP standard data access interface (ISO 10303-22)	Standard data access interface developed in Sable-project.	ISO 15926-7 Façade	No

Table 2. Comparison of the data models regarding the technical requirements.

Usability requirements are summarized in Table 3. STEP standards have traditionally suffered from the reputation of being complex. Reason for this is partially the fact that the topic of standardization is complex, but also that the standards contain a lot of references to each other and they use terminology that is not familiar in the implementer community. AP 227 and AP221 are not exceptions in this sense. However, AP221 includes a good set of examples making it easier to be understood. ISO 15926 seems even more problematic, since its basic data model is understood by only a handful of standard developers.

IFC is EXPRESS based, but some of the most complicated modeling methods have not been used that will probably make implementation easier. AEX, on other hand, is a pure XML Schema implementation. XML Schema is well know and easily implemented by most of the software developers, but it is more restricted modeling language than e.g. EXPRESS. ISO 15926 has also plans to publish its reference data library in OWL [17].

	AP227	AP221	IFC	ISO 15926	AEX
Understanda-bility	Requires STEP/ EXPRESS experts	Requires STEP/ EXPRESS experts	Easier to understand than most STEP based standards.	ISO15926-2 extremely difficult	Understood by XML experts.
Implementa-bility	Requires STEP technology.	Requires STEP technology.	Requires STEP technology.	Requires STEP technology. ISO15926-4 may use OWL in the future	Requires XML technology
Flexibility	Flexible conceptual model based on EXPRESS modeling.	Flexible conceptual model based on EXPRESS modelling.	Flexible conceptual model based on simplified EXPRESS modelling.	Flexible conceptual model based on EXPRESS modelling and extensions in ISO 15926-4.	Flexible XML schemas, with XML Schema restrictions.

Table 3. Comparison of the data models regarding the usability requirements

3.1. Summary

Table 4 summarizes the Tables 1-3. Comparing the data models (Table 4) is problematic since they each have different perspective on the data modeling and therefore the summary is naturally subjective.

	AP227	AP221	IFC	ISO 15926	AEX
Business requirements	±	-	-	+	+
Technical requirements	+	+	+	+	-
Usability requirements	-	-	±	-	+

Table 4. Summary of the data models regarding the requirements (+: positive evaluation, -: negative evaluation, ± neutral evaluation)

When summarizing the business requirements, the biggest differences can be found in information content and the status of the specifications. IFC is mostly concentrated on construction industry information, while the others cover whole process industry information. AP 221 specification development was suspended for a long period of time and also AP 227 is developing slowly, if at all. Since ISO 15926 and AEX are actively developed and they are planned to cover all the aspects needed in lifecycle management, it seems that the best matches of the business requirements are ISO 15926 and AEX.

Technical and usability requirements are harder to evaluate, since scopes of the specifications differ. In this research, long term integrity of data integration was given priority and therefore we conclude that the data models defined in EXPRESS community fulfill the technical requirements most comprehensively. However, the results might be different if the usability issues are prioritized: EXPRESS-based standards seem to be much harder to use and implement (with the possible exception of IFC that does not use all the EXPRESS constructs).

In practice however, business requirements are the ones that should be decisive when selecting the data model used in the company network. ISO 15926 and AEX both cover the business needs required. However, it must be noted that the both AEX and ISO 15926 are still mostly “promiseware”; only part of the promised specification actually exists while writing this paper. Also, there are mostly only “proof of concept” implementations of the specifications; no real business implementations exist.

4. Conclusions

In this paper, five data models developed or applied in the area of process engineering have been reviewed. The requirements for the data model were divided into three categories and the comparison of how the data models fulfill the requirements is summarized in the Tables 1-4.

The standards studied contain such a huge amount of knowledge about different aspects of the plant lifecycle information management that they should be used as a basis for any serious data modeling effort in the area.

It seems that in the short run AEX seems to be the standard that is most likely to become adopted in data exchange. However, in the long run ISO 15926 seems to offer solid base for data integration challenges of the future, assuming that it does not prove to be one of the long list of "committee standards" that never materialize into real world implementations. There are efforts of combining both the AEX and ISO 15926 approach, and the future will show whether they prove successful

In conclusion it seems that none of the current standards fulfils all the criteria given. ISO 15926 tries to cover whole plant life cycle, but introduces an extremely complicated data model, which has also been heavily criticized in the ontology community [18]. It seems that in the future we need methods on how to cope with multiple standards, a task which is studied in the Semill-project [19].

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System engineering applied to specification and characterisation of data management systems for collaborative engineering

T. Nguyen Van
Ecole Centrale Paris, Grande voie des vignes, 92295 Chatenay-Malabry Cedex, France
SNECMA (SAFRAN Group), Digital Mock-Up, Site de Villaroche – BP42, 77552 Moissy-Cramayel Cedex, France

B. Maillé
SNECMA (SAFRAN Group), Digital Mock-Up, Site de Villaroche – BP42, 77552 Moissy-Cramayel Cedex, France

B. Yannou
Ecole Centrale Paris, Grande voie des vignes, 92295 Chatenay-Malabry Cedex, France

J.P. Bourey
Ecole Centrale Lille, Cité Scientifique – BP 48, 59651 Villeneuve d'Ascq Cedex, France

ABSTRACT: Collaborative platforms are presently a growing concept to enable the concurrent development of product in the context of extended enterprise. Product design has seen around 10 years the increase of software solutions for 3D modeling and data management. Major consequence of such development is that amount of data created during a project has increased and the exchanges between partners around the product definition have become more difficult. This need to create a collaborative environment has developed the creation of such platform. This paper proposes to define a guideline for designing such collaborative environment by using system engineering concepts. It is explained the different integration fields that have to be considered on this topic. We finish this study by an application to the design and simulation integration for collaborative purpose.

1 INTRODUCTION

Nowadays, collaborative design for product development has become a classical practice. The increase of sub-contracting activities and partnerships between companies in the aeronautic industry leads to consider the extended enterprise context. As design technologies have also evolved through 3D modeling and data management solutions, enterprises are facing the need to integrate their working environments in kinds of "collaborative platforms or collaborative hubs".

Such collaborative solution appears as necessary to enable the different partners of a project to communicate in the most meaningful way. As we are evolving toward a growing use of the "virtual product", the need of data exchange and data "quality" is also increasing the need to develop more complex platforms. That way, they are no more based on single data import and export, but integrated with tools and relevant of the product attributes that need to be exchanged. While considering an activity, the use of such platform must enable to reveal the context created around the product, and the different objects used to transform this working space (e.g. tools and information technology systems).

In actual platform development, implementations are regulated step by step using end-user requirements without taking into account the capability identified to answer the major requirements enforced in ISO 9126-1 [16] as functionality, reliability, usability, efficiency, maintainability, portability.

In this broaden environment of solution proposals, we identify system engineering as a necessary approach to answer the design of these platforms. Based on the identification of major fields to be implemented for communication and exploitation of meaningful objects, we are proposing a method based on activity context, product and resources models. This work is motivated by the need to extend collaborative platforms out of the boundaries of enterprises so as to enable coherency and integration of resources for projects.

Section 2 explores the collaborative engineering and the growing need of using collaborative elements. It underlines the recent from stand-alone data management systems to integrated environments for design. It defines the need for enterprise modeling and characterizes the necessary interfaces to construct such systems. Section 3 relates our system engineering approach for the definition of collaborative platform. Based upon specifications and characterization of the environments, we define high-level models structure for information convey-

ing. Section 4 illustrates our proposal with the definition of such system for design/mechanical simulation system. Finally, section 5 concludes this approach and opens perspectives.

2 COLLABORATIVE ENGINEERING AND DATA MANAGEMENT SYSTEM SPECIFICATION

Collaborative engineering is nowadays a necessary approach to reach the objectives of product development (e.g. lower costs, better development time, and quality) in the scene of extended enterprise. Distributed design activities to the different partners and sub-contractors have involved the need to define a common referential to enable the coherent and meaningful development of the product. In part of the evolution of the different software for design and data management, exchanges between partners have evolved from simple and single file to integrated environment [4, 12]. Although, while they were limited to design environment a few years ago, such environment use is now extended to the different processes identified in the enterprise (from design to manufacturing) and to the different phases of a project (from preliminary to service).

Such approach is justified through the need to enhance the integration of the different "design chains" [4]. This is moreover truth if we consider the approaches of Fuh & Li [4] and Li et al. [8] that propose integrated mechanisms for distributed engineering. Such mechanisms rely on the association of two approaches for product development:

- A static approach: Defined to associate the static elements of the product definition. For example, it defines the product data model made of product attributes (Id, name, maturity, version, exchange date…). This is designed with classical modeling tools such as UML (Unified Modeling Language) or EXPRESS (ISO 10303-11).
- A dynamic approach: this one is more relevant of the processes/workflow approach. It defines activity sequences and describes the different actions on data. For example, it defines the process of simulation in terms of input/output and transformation objects that act on data. This is designed with classical modeling tools such as IDEF0 (ICAM DEFinition language).

Major collaborative architecture proposes these two kinds of approaches. Bergman & Baker [1] describe a « shared virtual workspace » that aims at enabling the data exchange through integrated environments. Each environment is submitted to its own laws of functioning. While considering the architectural purpose, Fuh & Li [4] propose in their article a classification of integrated and collaborative environments based upon three categories:

- Thin server and strong client: In which data are pushed from standalone environments to an integrated one
- Strong server and thin client: In which data are directly handled in the integrated environment from the different standalone environments.
- Peer-to-peer: In which files are directly exchanged through services between standalone environments.

This contributes to the definition of integrated infrastructures for design in collaborative environments with multi-view application (design, simulation…) purpose [1, 4 and 8].

Major objective of such architecture is to provide efficient data management systems such as those proposed by the classical Product Lifecycle Management (PLM) systems but also to extend them for collaborative environments. Their role is to provide shared spaces for the different partners and in part of the activity they have to perform.

They are dedicated to define application, physical and business integration to enable the business process [5]. That way, collaborative platform has to ensure tools communication and data interoperability in the most meaningful way. For the dynamic approach, such platform must define services to create requests on activities and provide inter-enterprises workflows. Furthermore, they have to ensure the NIST (National Institute of Standards and Technology) recommendations mentioned by Sudarsan et al. [14] on:

- Formal semantic or appropriate ontology to enable automatic reasoning
- Generic: deals with general entities so as to be universal enough
- Repository: to contain all the data relative to product
- To foster the development of novel applications and processes
- To incorporate the explicit representation of design rationale
- To convert and/or interface the generic representation schemes with a production-level interoperability framework

Objective is to create networked activities around product data representation, and more especially around a referential created for the product in the collaborative workspace [10].

In this stream, many approaches have been used such as association of a middleware with web services, association of models in integrated environment, creation of distributed business processes or platforms using enterprise modeling approaches such as CIMOSA.

Perrin & Godart [10] expose in their paper a centric approach based on a middleware solution and

implemented with web services. Such approach enables to define a collaborative environment and repository for data. Middleware is a solution based on thin server and strong client solution. It enables through web services to access the data. But in such principle data have to be "pushed" by the users in the collaborative environment. Sudarsan et al. [14] propose another solution based on models association in order to create a kind of PLM structure that is a support framework for product information. Expected benefits rely on the capability to access, store, serve, and reuse product information all along lifecycle. In their paper Gou et al. [5] proposes to structure distributed business process. Based on UML description, they propose multi-agent solution to develop operations on business processes. In the same research stream, Loureiro & Leaney [9] propose an approach for what they called "total view framework" which enable the definition of the enterprise model at different levels.

The different architecture of such collaborative framework rely on the definition of multi-layered architectures based on the integration of multiple components to serve the business processes with the use of models templates [10, 9, 14].

At this level, enterprise modeling and integration (EMI) is identified as a necessary approach to enable collaborative approach. This consists in defining business processes and the explicit/implicit plugs that can exist between them. After Vernadat [15], enterprise integration consists in "breaking down organisational barriers" and enterprise modeling consists in "making models of the structure, behavior and organization of the enterprise". Enterprise modeling and integration then consist in defining models regarding different levels of the enterprise to analyse as close as possible the different processes exploited. The next step consists in the organisation of these models so as to exploit the different available plugs between processes to integrate them [see modeling and state-of-the-art definitions of Shunk [13] and Reithofer [11], and examples of use by Delen [3] and Vernadat [15]]. Different methods and literature around methods called CIMOSA (Open Systems Architecture for Computer Integrated Manufacturing Systems) and FIDO (function, information, dynamics, and organization modeling method) propose such approach of modeling enterprise within a multilevel approach.

Using such approaches to define the context of designing an Information Technologies (IT) system to support collaborative design relies on the statement that using these different approaches is still not defined enough. Considering the different shifts in enterprise structure and project constraints (especially in aeronautic domain), there is a need to define an integrative approach based on system engineering.

3 PROPOSED APPROACH

In this paper, we propose a method to characterize and design collaborative engineering platforms. This approach first characterizes the major requirements incoming from aeronautic industry. Second it proposes the characterization of major objects that have to compose the environment of collaborative platform.

The environment we are proposing this study is based on the aeronautic industry. In product development program, integration relies nowadays on the virtual product called Digital Mock-Up (DMU). This technology has already enabled to decrease development cycle and physical prototyping. Nowadays with the amount of data created and managed by the different partners of a program, the need of creating a centralized structure relies on the need to create a common referential for the different partners. Major idea is based upon the realization of centralized repository enabling the different partners to manage data for multi-activity purpose.

By analyzing such collaborative architecture aims, we have defined 6 major requirements to answer:

- Define a common data referential: ensured through data vault and files management. It should enable the storage and the retrieval of product data all along its lifecycle. This should also enable the coherency of data while considering configuration management, standardised components…
- Manage information between partners: ensured with file formats association. This should enable to define the meaningful way to manage data. Models should describe the attributes attached to product and must manage the different attributes links between partners systems.
- Provide Major PLM functions: must define the major actions on data and enable the management all along lifecycle.
- Provide data context: must enable to retrieve the right context of data use. For example provide CAD (computer aided design) models for design and Finite element models for simulation. This must also enable to retrieve the necessary interfaces to help partners to position their design on the final virtual product.
- Provide associativity of data: must enable to define the links between data created by the different activities. For example, it must enable to associate a 3D model to a finite element model.
- Define flows and processes plug: must enable to define the different ways to access partners' processes.

To answer such requirements, we defined 5 major stages of analysis. These five requirements follow a bottom-up approach from end-user view characterized through the data topic, going through tools, processes and finally high-level processes. The last stage is the integration that enables us to characterize the different plugs that need to be implemented through the four first stages.

- Definition of data typology: Define what kind of data is accessible by what kind of actor. This defines the different views to associate to data and the links can exist between data.
- Definition and tools analysis: Define what are the tools data models and available plugs to define the connection to a collaborative platform. This should enable us to define attributes exploited and the way they are managed so as to extract the most relevant data structure.
- Processes structure definition: Define processes and associated models to identify the different available process interfaces that can be accessible to launch work requests.
- Context / Product / Resources coupling: Define the necessary elements for contextual approach. It defines the major links available between high-level objects. This coupling between context, product and resources precise what we called the context.
- Integrative approach: The integrative approach is the element that enables us to characterize the plugs available all along the definition of objects. From data connection point of view, it is characterized through attributes links between models. For tools connections, it is performed with API's programs or formats definition. For processes, it is defined by workflow interfaces, and finally for business it is ensured through project relations.

Figure 1 presents the view these five stages are performed. Data typology enables to define the different attributes of product use in a kind of activity. Integrative approach means that attributes are related one to each other between the different typology. For example, while considering the serial number expressed in design data typology, this one must be retrieved in the simulation data typology. These attributes are then relevant for a tool (for example for a PDM system). They are then associated from a tool to another in regards with typology established. Then the tool is used to transform a data in a defined activity or process. For the integration, association between two processes results in defining an association between data using work requests through workflows. At higher level the enterprise model will define plugs at the project level.

These stages are also implemented with the necessary elements of such architecture.

- The data vault and files management that enable storage and retrieval of product data in its entire lifecycle. They enable this storage and retrieval by managing the links between data models and attributes.
- The workflow and process management define information paths and the plugs between processes that can be associated.
- The product structure and configuration management that handle the product description through the Bill Of Material (BOM) and configuration description.
- The part management that corresponds to the different standards components and libraries .It also corresponds to the standard association between components, and manages theses information in meta structure of classification and groups.
- The converters correspond to the management of the different data formats. It enables the mapping of the applications in part of the information they can use.
- The project management provides the Work Breakdown Structure (WBS) and provides relevant information about the association between resources and activities.
- The functions provides the capabilities on data logistics (transport, translation), communication, system administration, and data security

Figure 2 present the UML vision of Figure 1. The different data concerning product and its development (e.g. product data, physical files, components library, knowledge base and requirements) are stored in the collaborative repository. The definition of the tools schema and processes enables to define what we called interface model and context schema. These models must enable to filter data from the collaborative repository. Product attributes are then conveyed through these "interface" to the tool for end-user. In fact such tools are used to complete an activity. This one, generated through work request will define the essential characteristics of the context. Once activity is performed, the work output will implement a workflow object to send new work order and then request of activity for another end-user.

Figure 3 present the UML sequence diagram associated to Figure 2. In a first step, we consider that a workflow object implemented in a tool is sent to the user. While looking at the activity to perform, he uses a tool and sends a request to retrieve relevant data. The tool request is filtered through the context schema that enables to define the exact data that need to be extracted in the collaborative repository. Then data of the collaborative repository are mapped and characterized through the context model and in-

terface model before they are sent to end-user tool. Once he has data, the end-user is then able to perform the requested activity. Once he finished, he has to execute a notification to enable the tool to distribute the new data created to the repository. In fact, data are filtered before using the interface model to determinate what kind of attributes on product have been created and what have been the actions on them. Then, it is possible through the notification to implement the workflow object and notify that work activity is performed and send new requests of activities.

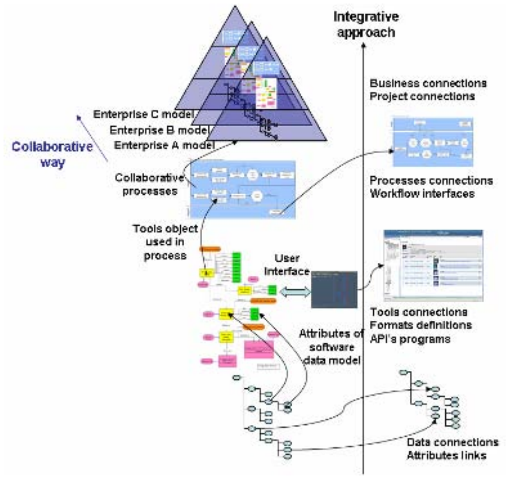

Figure 1 - Sequence of the five stages for engineering a collaborative platform

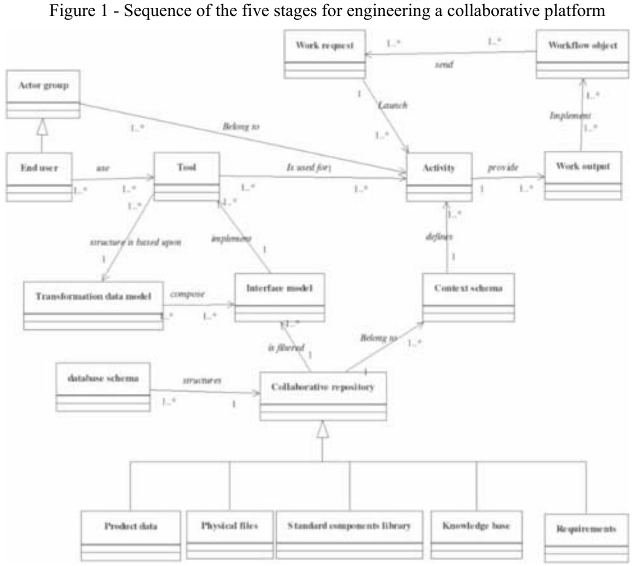

Figure 2 - Implementation UML model for collaborative approach

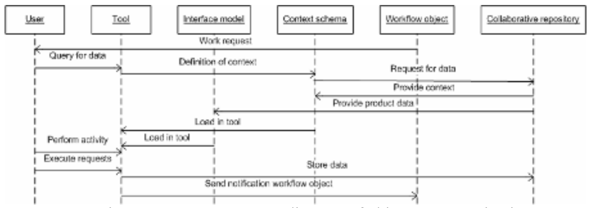

Figure 3 - UML sequence diagram of objects communication

4 CHARACTERISATION FOR DESIGN / SIMULATION DATA MANAGEMENT IMPLEMENTATION

Here, we propose to implement the previous analysis with a study on design and simulation optimization loop. This case is relevant because of the interactions existing between these activities. Presently, integration of these activities in a collaborative way is still not well demonstrated through classical approaches. This study is made of three main parts:

- First, a typology of data and a study of classical tools used for these activities.
- Second, a definition of models to illustrate what is described in previous section.
- Third, a functioning principle identified on these two activities

While looking at these two activities we can classically extract the following data use:

- Product Data Management system: relating Bill-Of-Material, configuration, and major attributes of the product.
- 3D design models: mainly provided through activities on CAD systems
- Simulation Data Management system: relating the same attributes as PDM systems, and mainly implemented on load cases, boundary conditions…
- 3D finite element models: mainly provided through activities on CAE (computer aided engineering) tools such as Patran….

These different objects can be associated such as depicted in Figure 4.

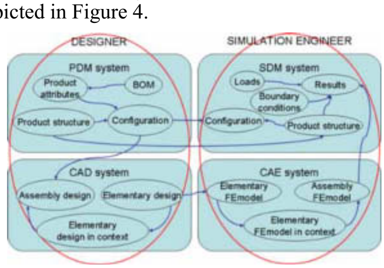

Figure 4 - Simple data typology for Design and Simulation activities

This typology enables to establish a first implementation on integration between the data. While looking at such industrial topics (3D models and data management), we can identify the potential use of ISO 10303 (STEP for STandard for Exchange of Product data). Looking at the semantic available, it is possible to identify that the Application Protocol 209 [18] deals with geometric considerations and mechanical analysis. Although Application Protocol 214 [17] enables to define objects from data management systems such as configuration, document structure…This combination of data typology and communication objects defines the first steps for the implemented view of an architecture. Based on section 3 and within the analysis of processes, we are able to design the first architecture objects presented in Figure 5.

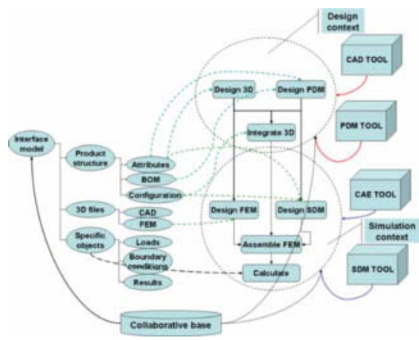

Figure 5 - Integration between tools, data and processes view

Figure 5 presents the linked objects in the field of data represented through the interface model and collaborative data, the processes (quite elementary in this example) and the tools used.

Figure 7 present the high level view we have created to manage the overall design and simulation in this context. This model is designed with an EXPRESS-G tool, this view enable to characterize the overall data and information that have to be manipulated in such context. EXPRESS-G is a modeling language based on ISO 10303. EXPRESS-G supports a subset of EXPRESS and, by its visual representation in compact form, furthers the understanding of the data model. The basic elements of EXPRESS-G are shown in the following overview:

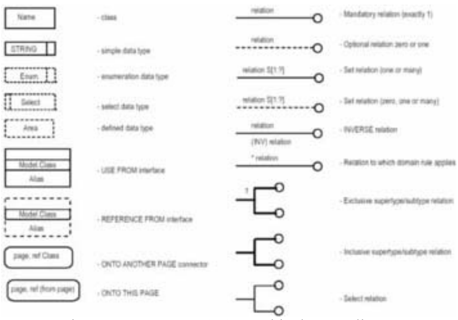

Figure 6 - EXPRESS-G Graphical Formalism

In Figure 7, we present the association of the three major elements to be considered in such approach:

- We defined first the Aircraft_Information_Data that enable us to define the generic model for data management systems, define the views associated to product and define the storage of requirements
- Second, the Aircraft_Activity_Resources that deals with tools data structure, services implemented (request objects) and components that enable to point the different library and knowledge databases
- Third, the Aircraft_Activity_Context characterizing the process approach, the project, and identified milestones.

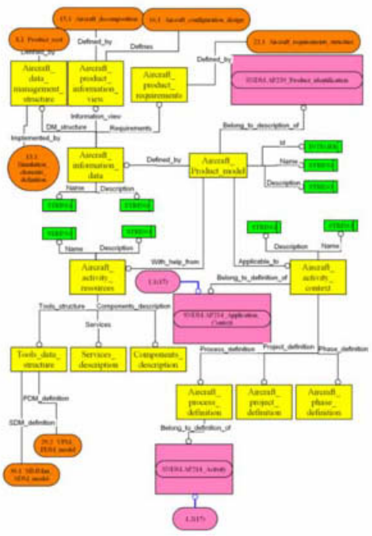

Figure 7 - High-level view in EXPRESS-G of the interface model defined in section 3 applied to the characterisation of aeronautic environment for design and simulation

These elements are grouped under the same entity we have defined as the Aircraft_Product_Model. The model presented in Figure 7 present the implemented view of the UML model described in Figure 2. Tools, interface models and transformation models of Figure 2 are described in the Aircraft_Activity_Resources of Figure 7. This entity describes the data model of software, introduces the notion of configuration and of requirements attached to the product definition. From a more pragmatic point of view these models are for example responsible of data translation from PDM system to SDM system. Figure 8 illustrates this principle. The exported data from a tool are going to be mapped by our model. Then attributes will be instantiated to another model that will be the basis to create data ready to be imported.

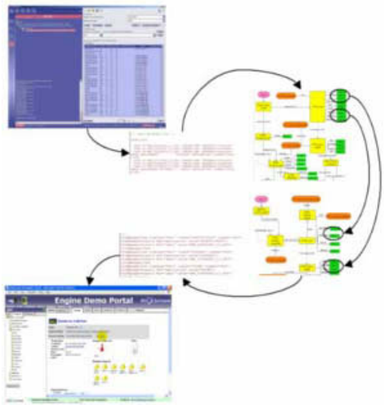

Figure 8 - Representation of functioning principle

The part Activity (with work request and workflows) of Figure 2 is described with the Aircraft_Activity_Context of Figure 7. This describes and defines the project, phase and process attached to the context of product definition. Finally, Aircraft_Information_Data in Figure 7 represent the consolidated repository structure of Figure 2 by providing data models of data structure.

5 CONCLUSION – FURTHER WORK

The development of extended enterprise and collaborative engineering around the virtual representation of the product has seen a limit during past years. Companies are now submitted to the development and implementation of collaborative workspaces in their systems so as to attain new performance gains in terms of data availability and coherency. These collaborative workspaces lead us naturally to consider first a shared database. But in

this bulk environment of 3D modeling software solutions and data management systems, such collaborative environments has to be extended to the definition of an interoperable and associative environment for data. This paper proposes to define the setting environment to answer major specifications of such system. Based on models and interoperable standards such as STEP, the advantage of what we present here is the integration of product view, context definition and resources (e.g. tools, databases…). We also highlight the implementation that can be made within the industrial viewpoint. The overall perspective of this paper is to enhance the dissemination of methods based on this collaborative approach and to enable the development of the current studies made at Snecma.

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P. Ghodous et al. (Eds.)
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A Critical Assessment of ISO 13584 Adoption by B2B Data Exchange Specifications

Joerg LEUKEL[a], Volker SCHMITZ[b] and Martin HEPP[c]
[a]*University of Hohenheim, Stuttgart, Germany*
[b]*University of Duisburg-Essen, Essen, Germany*
[c]*DERI, University of Innsbruck, Innsbruck, Austria*

Abstract. Recently, the ISO 13584 standard for parts libraries (PLIB) has been widely discussed as a reference model for developing product ontologies, such as product classification systems and standardized property lists. For instance, major industry consortia have announced their intention to incorporate this standard into their product dictionaries and related data exchange specifications. Implementing these PLIB-compliant dictionaries is often regarded as an important step for overcoming heterogeneity in product descriptions and enabling automated cross-industry communication centered on product information. While many industries are aware of PLIB's potential contribution to semantic interoperability (and some have already started providing PLIB-compliant content), the actual degree of support by B2B data exchange specifications may be a limiting factor to wider diffusion. In this paper, we (1) analyze the current degree of ISO 13584 adoption in such specifications, (2) determine how this adoption has changed over time, and (3) identify existing gaps between ISO 13584 and XML-based specifications.

Keywords. Product Data Management, PLIB, ISO 13584, Ontologies, XML, Standards

1. Introduction

Many important business processes, such as procurement, distribution, engineering, and fulfillment, refer to or process information about products (and services). In order to increase market transparency, and to enable product comparison and automated process execution between multiple, often independent business entities in open and increasingly flexible business environments requires a consensual representation for categorizing and describing products [1] [2]. Both functions, the categorization of products by providing a hierarchy of product categories as well as the description of products by defining category-specific product properties, are being addressed by the ISO 13584 standard (PLIB) [3]. Basically, PLIB standardizes a comprehensive data model for product categories and properties. It can be used by business partners as well as industry consortia and standardization bodies for defining respective content; in the latter case, content standards such as product classification systems (e.g., UNSPSC, eCl@ss, and the RosettaNet Technical Dictionary) can be based on ISO 13584 [4] [5].

Bringing ISO 13584 into real-world business applications is only possible if it is widely adopted by decision makers, content creators, solution providers, and related B2B integration technology, such as data converters and data exchange specifications. The latter is especially of importance for most of the current B2B scenarios, which were driven by the emergence of e-procurement and e-marketplaces systems in the late 1990s. This first wave of B2B e-commerce had resulted in a great number of XML-based data exchange specifications and underlying data models for product data and related business transactions. These were either inspired by existing EDIFACT specifications or developed completely from scratch [6]. In recent years, many industries have identified PLIB as an essential tool for reducing heterogeneities in product categorization and description on the conceptual level. However, actual support by B2B data exchange specifications may remain a substantial barrier to wider acceptance and industry-wide diffusion, since PLIB itself lacks an XML-based exchange format.

The contribution of our paper is as follows: We (1) critically assess the current degree of ISO 13584 adoption by B2B data exchange specifications, (2) determine if and how this adoption has changed over the past five years, and (3) analyze existing gaps between the ISO 13584 model and current XML-based specifications. The remainder of our paper is structured as follows: In Section 2, we describe and discuss related work and explain the missing link between ISO 13584 and its adoption in B2B e-commerce. In Section 3, we define a comprehensive set of criteria that allow us to assess ISO 13584 adoption. In Section 4, we apply these criteria to the most relevant B2B data exchange specifications and provide an in-depth analysis of their PLIB adoption. In Section 5, we discuss our findings. Finally, Section 6 draws conclusions from our findings and points to future research and development.

2. Related Work

Related work to product classification and description and its respective standards and technologies can be found in diverse fields such as product data management, interorganizational information systems, and ontology engineering. Next we describe only work that addresses the role of standardization explicitly.

Research on ISO 13584 emphasizes the ontological aspect and its contribution to semantic integration. In this context, all data exchange is assigned to PLIB's own exchange format that is specified in the EXPRESS language of STEP and results in non-XML data files; e.g. [7] [8].

In 2002, Leukel et al. described the process of developing an XML-based exchange format being capable of transferring the classification schemes eCl@ss, ETIM, proficl@ss and UNSPSC/EGAS without loss of information [9]. However, this early work did not consider ISO 13584 at all.

A CEN workshop on e-cataloguing has resulted in a broad survey of data exchange formats for e-catalogs [10]. The respective project report contains a comparative analysis of 14 formats (11 being XML-based), though the product classification and description part is very shallow with only checking whether it is possible to define this content (but not how to do it). The workshop concludes that ISO 13584 adoption is insufficient and further standardization work should be undertaken.

More recently, CEN has set up a project on developing the aforementioned specification in order to submit it to ISO TC 184 for approval [11]. The result is called

OntoML, an UML view on the complex PLIB model complemented by an XML schema for data exchange.

Several representations of product classification schemes for the Semantic Web have been proposed. In consequence, respective specifications apply formal languages, such as RDF and OWL [12] [13]. For instance, Hepp has presented a methodology for deriving OWL ontologies from existing schemes and converted eCl@ss into such an ontology [14]. Again, ISO 13584 is not considered here, since all this work takes existing, non PLIB-compliant content as the starting point and aims at “ontologizing” it.

The brief discussion of related work points to the fact that either (1) PLIB itself is widely neglected (i.e., [9] [14]) or (2) the data exchange issues are limited to the PLIB world, thus the prevailing commercial B2B specifications are neither considered nor integrated (i.e., [8] [11]). Therefore, the need for a closer investigation of the complementary relations between PLIB as the conceptual data model on one side and exchange specifications on the other side becomes clearly evident.

3. Criteria for Assessing ISO 13584 Adoption

In this section, we define a comprehensive set of criteria that allow us to assess ISO 13584 adoption. In our context, adoption is an abstract term describing any kind of guidance, support, and implementation, may it be either complete or not. PLIB adoption can be assessed primarily by comparing its schema with the respective data exchange specifications. This approach also requires identifying whether PLIB’s basic concepts for representing categories, properties, and their relationships to each other are followed. In B2B scenarios, dictionary content can be exchanged between organizations developing classifications, buyers, intermediaries, and suppliers; 9 specific exchange relationships are being described in [4]. In addition to transferring dictionaries, we will have to consider the *usage* of dictionary entries in various business transactions, such as manufacture-to-order processes.

3.1. Terminology and Basic Concepts

Since the scope of PLIB has been extended towards e-procurement and e-sales, we replace in the following the original term ‘family of parts’ by the more abstract ‘product category’ or ‘category’. Note that both in literature and practice, many other terms are frequently used (e.g., class, group, and concept). Therefore, we incorporate terminological aspects into our analysis in order to unfold the existing diversity with regard to the most essential terms.

PLIB implements a number of basic concepts that help building consistent dictionaries containing unambiguous definitions of reusable dictionary entries. Here, we briefly describe only those concepts (1) that have to be adopted by data exchange specifications and (2) that can not be assessed by analyzing the models for categories and properties isolated:

<u>Separation of property definition and property application:</u> This concept requires two steps. First, each property has to be defined as far as possible independently from the categorization; that means independently from its application in a specific context. However, often the definition on the top level is not feasible because properties can be interpreted differently in the context of different categories (e.g., the measurement of height might differ between a table and a valve) [8]. This information is called

definition scope. Second, these well-defined properties can be used in multiple property lists; hence they are mapped to more detailed categories [11, p.37].

Property inheritance: Considering that properties are assigned to categories forming a classification hierarchy, property inheritance says that properties are inherited to all lower categories [11, p.38]. Moreover, an inherited property can be modified on subsequent lower levels. For data exchange, this concept can be implemented by allowing properties being mapped to intermediate categories (nodes) of the classification tree. It has to be emphasized that this procedure is only feasible if the classification tree is truly based on is-a-relationships; currently, these relationships can rarely be found in most existing product classification schemes [14].

Domain restriction by values: Properties have at least a data type assigned, such as string, integer or float. However, very often product characteristics need to be expressed by selecting a value from a list of allowed, predefined values (enumerative type). In PLIB, this concept is being represented by a tertiary relation between category, property and value [11, p.39]. Domain restrictions by value lists have to be mentioned here, since single values are not dictionary entries, though they can be defined by a value code (as identifier), the value itself, and a reference to a document defining the value and its meaning.

3.2. Definition of Dictionary Entries

The definition of dictionary entries is the main subject of PLIB: it provides a data model (or schema). Data exchange specifications are nothing but schemas for the same subject, though they specify how to serialize the dictionary content by using an XML schema language such as XSDL or XML DTD. Comparing these schemes requires raising XML schemes to the conceptual level; thus we need to identify if dictionary entries can be fully represented respectively transferred by these specifications. Therefore, we abstract from the actual serialization and XML document structure; instead we look at the attributes describing the two main types of dictionary entries.

The list of attributes describing categories and properties can be extracted directly from the PLIB model; these are contained in ISO 13584-42 in sections 8.2 and 7.2 [15] [16]. However, it is not sufficient to look for the existence of these attributes or its equivalents only, since PLIB follows a strict, sophisticated data typing, similar to precisely defined data exchange specifications formally described in XSDL. Therefore, we check for each attribute the data type and possible domain restrictions.

3.3. Usage of Dictionary Entries

Once dictionary entries have been defined, they can be used in actual business transactions. Due to global unique identifiers (GUID) for all entries, the usage requires only referencing these entries. In the Semantic Web world, this procedure is called annotating content. For instance, actual products in catalogs can be mapped to a category and described by category-specific properties. The latter adds a value by adhering to the defined domain or picking a value from the list of allowed ones.

Here, PLIB adoption can be assessed by looking for message types that allow references to dictionary entries. The range of message types and respective business processes is not limited to exchanging master data, such as catalogs. The reason is that a product's category and its property values determine many business processes. This information adds value to supply chain management and automated business process

execution; hence it should be included in respective inter-organizational information systems and message specifications [17].

4. Analysis of B2B Data Exchange Specifications

In this section, we apply our assessment criteria to the most relevant B2B data exchange specifications and provide an in-depth analysis of their PLIB adoption. The first step of our analysis is the selection of relevant specifications. We take the CEN study on e-catalog data exchange as a starting point (for details on each specification see [10]). Of the 11 XML-based specifications described there, we chose all but two (which have become obsolete in the meantime). Conducting the analysis incorporates (1) accessing the most recent versions from the respective websites, (2) studying both documentations and XML schemes, (3) documenting the findings in detailed mapping tables, and (4) summarizing the results as presented in the following four tables.

The first table lists the various terms used for naming the two essential objects, categories and properties. In addition, it shows which of the three basic concepts are actually adopted by the respective specification (yes/no).

Table 1. Terminology and basic concepts.

ISO 13584	BMEcat 1.2	BMEcat 2005	CIDX 4.0	cXML 1.2.014	eCX 3.6	GS1 BMS 2.0	OAGIS 9.0	Rosetta Net	xCBL 4.0
Date of publication	Mar. 2001	Nov. 2005	2004	Oct. 2005	Nov. 2003	Nov. 2004	Apr. 2005	Dec. 2003	Jun. 2003
Terminology: Family of parts	Classi-fication group	Classi-fication group	Product classifi-cation	Classi-fication	Catego-ry	Classi-fication catego-ry	Classi-fication, Comm-odity	Classi-fica-tions	Catego-ry
Terminology: Properties of parts	Feature	Feature	Product specifi-cation	Type-Attribu-te	Attribu-te	-	Proper-ty, Specifi-cation	Charac-teristics, Attribu-te	Attribu-te
Separation of property definition and application	No	Yes	No	No	Yes	No	Yes	No	Yes
Property inheritance	Not ex-plicitly	Yes	No	Yes	No	No	Not ex-plicitly	No	Yes
Domain restrictions by values	Yes	Yes	No	Yes	No	No	No	No	Yes

The next two tables show which of the 15 respectively 21 attributes that describe categories respectively properties are actually supported by each specification. PLIB's mandatory attributes are marked with 'M', its optional attributes with 'O'.

Table 2. Attributes that describe categories.

ISO 13584		BMEcat 1.2	BMEcat 2005	CIDX 4.0	cXML 1.2.014	eCX 3.6	GS1 BMS 2.0	OAGIS 9.0	Rosetta Net	xCBL 4.0
Code	M	Yes	Yes	No	No	Yes	No	Yes	No	Yes
Superclass	O	Yes	Yes	No	No	Yes	No	Yes	No	Yes
Preferred name	M	Yes	Yes	No	No	Yes	No	Yes	No	Yes
Short name	O	No	Yes	No	No	No	No	No	No	No
Synonymous name	O	Yes	Yes	No	No	No	No	No	No	No
Definition	M	Yes	Yes	No	No	No	No	No	No	Yes
Source document of def.	O	No	Yes	No	No	No	No	No	No	Yes
Note	O	No	Yes	No	No	No	No	Yes	No	Yes
Remark	O	No	Yes	No	No	Yes	No	No	No	No
Simplified drawing	O	No	Yes	No	No	No	No	No	No	No
Date of original def.	M	No	Yes	No	No	No	No	No	No	No
Date of current version	M	No	Yes	No	No	No	No	No	No	No
Date of current revision	M	No	Yes	No	No	No	No	No	No	No
Version number	M	No	Yes	No	No	No	No	No	No	No
Revision number	M	No	Yes	No	No	No	No	No	No	No

Table 3. Attributes that describe properties.

ISO 13584		BMEcat 1.2	BMEcat 2005	CIDX 4.0	cXML 1.2.014	eCX 3.6	GS1 BMS 2.0	OAGIS 9.0	Rosetta Net	xCBL 4.0
Code	M	Yes	Yes	No	No	Yes	No	Yes	No	Yes
Data type	M	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes
Preferred name	M	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes
Short name	O	No	Yes	No	Yes	No	No	No	No	No
Preferred letter symbol	O	No	Yes	No	No	No	No	No	No	No
Synonymous letter symb.	O	No	No	No	No	No	No	No	No	No
Synonymous name	O	No	Yes	No	No	No	No	No	No	No
Property type classific.	O	No	Yes	No	No	No	No	No	No	No
Definition	M	No	Yes	No	Yes	No	No	No	No	No
Source document of def.	O	No	Yes	No	No	No	No	No	No	No
Note	O	No	Yes	No	No	No	No	Yes	No	No
Remark	O	No	Yes	No	No	Yes	No	No	No	No
Unit	M	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes
Condition	O	No	Yes	No	No	No	No	No	No	No
Formula	O	No	No	No	No	No	No	No	No	No
Value format	M	No	Yes	No	Yes	No	No	No	No	No
Date of original def.	M	No	Yes	No	No	No	No	No	No	No
Date of current version	M	No	Yes	No	No	No	No	Yes	No	No
Date of current revision	M	No	Yes	No	No	No	No	No	No	No
Version number	M	No	Yes	No	No	No	No	No	No	No
Revision number	M	No	Yes	No	No	No	No	No	No	No

In the final table, we present the results for the usage of dictionary entries. These are (1) the way how to reference a category or property and (2) the list of message types allowing such references, if any. For our analysis, we chose the catalog message plus five message types representing the most relevant interactions between business partners in pre-order and order management processes.

Table 4. Usage of dictionary entries.

	BMEcat 1.2	BMEcat 2005	CIDX 4.0	cXML 1.2.014	eCX 3.6	GS1 BMS 2.0	OAGIS 9.0	Rosetta Net	xCBL 4.0
Reference of Categories	Yes	Yes	By name	Yes	Inter-nal only	Yes	Yes	UN-SPSC+ RNTD	Yes
Reference of Properties	By name	Yes	By name	No	No	No	By name	No	Yes
Message types (C=category reference; P=Property reference; '-'=no such message type)									
Catalog	C+P	C+P	C+P	C	No	C	C+P	No	C+P
Request for quotation	No	No	C	-	-	-	C+P	No	No
Quotation	No	No	-	-	-	-	C+P	No	No
Order	No	No	C	No	-	No	C+P	No	P
Order change	No	No	C	-	-	-	C+P	-	P
Order response	No	No	C	-	-	No	C+P	No	P

5. Discussion

In this section, we discuss our findings and relate them to the goal of our analysis. The first question concerns the current degree of ISO 13584 adoption. Obviously, none of the message specifications is fully compliant with PLIB. Reviewing the detailed data models and attributes for categories, we can make the following statements:

- 4 out of 9 specifications do not at all support the definition of categories.
- 4 specifications provide a rudimentary data model for categories, with only basic attributes, such as code, superclass and preferred name. Only BMEcat and xCBL contain PLIB's mandatory attribute for a human-language category definition.
- Only BMEcat 2005 covers all requirements expressed by the set of PLIB attributes.

Regarding properties, there is a similar situation as with categories:

- 3 out of 9 specifications do not contain a respective data model.
- 5 specifications have a sparse data model covering only basic information, such as code, name, and data type. The specifications differ in coverage with regard to the other attributes, though none shows a significant higher degree of coverage. cXML ignores the code attribute.
- Again, BMEcat 2005 has the most detailed data model, very similar to PLIB. However, it is not complete (two attributes are missing) and does not follow all of PLIB's attribute domains (i.e., definition of value formats and data types).

The second result of our analysis addresses the question whether PLIB adoption has changed over time. This question was based on the assumption that recent developments in product classification pointed out that PLIB could become a widely-accepted standard for the definition of product ontologies [8]. Interestingly, the empirical results show that almost all relevant specifications have not yet adopted PLIB in their most recent releases. For instance, both CDIX and OAGIS have been subject of major revisions over the past three years, though the data models for categories and properties were only slightly improved. Other specifications, such as eCX, RosettaNet and xCBL, are nearly static. Therefore, we did not include multiple versions of the same specification in the tables of Section 4. The only exception is BMEcat 2005, which has not only been substantially extended regarding its data models in

comparison to the preceding version BMEcat 1.2; still, it is the only specification that explicitly mentions ISO 13584 in its documentation. BMEcat 2005 claims that it 'is oriented to a large extent at ISO 13584'. While this is a first step into the right direction, we have to stress that 'orientation' is a weak form of adoption. For instance, BMEcat 2005 follows a proprietary approach for naming attributes and defining data types and value formats respectively.

The third question addresses existing gaps in PLIB adoption towards the support of business processes and related transactions. At first sight, we observed that the way of referencing dictionary entries differs with from PLIB's fundamental concept of GUID. CIDX references categories by their name only and thus fails to support multi-lingual content delivery and respective applications. Two more specifications are confined to a specific dictionary (e.g., UNSPSC). For properties, the situation is even worse, with only BMEcat 2005 and xCBL 4.0 allowing references by identifiers.

The closer look at message types unveils that using dictionary entries is hardly possible. Only the catalog transaction, thus the transfer of master product data, shows a high coverage with 7 out of 9 specifications supporting category references. Speaking of the more frequent business process transactions, only three specifications support any form of usage: (1) CIDX allows category references in 4 out of 5 message types, (2) OAGIS allows both references in all 5 message types, and (3) xCBL allows property references for order management, but not for pre-order management. Combining these observations with the previously assessed way how to give such references, both CIDX and OAGIS fall behind due to ignoring the GUID concept, which is necessary for multi-lingual dictionaries. All other specifications fail to provide any form of referencing, if respective message types are available. The overall situation shows a huge gap in PLIB adoption with regard to its applicability in actual electronic business processes.

6. Conclusions

In this paper, we have critically assessed the current degree of ISO 13584 adoption by B2B data exchange specifications. We determined if and how this adoption has changed over the past five years. This allowed us to identify a number of existing gaps between the ISO 13584 model and current XML-based specifications.

Specifically, we (1) have shown that the majority of the analyzed specifications fails to support PLIB and its basic concepts. Even the most comprehensive specification BMEcat 2005 is not fully compatible. However, it should be noted that it explicitly mentions ISO 13584. In other words, PLIB has found its way into at least one current B2B XML format. Another issue that complements our data model analysis and its apparent results is the domain of terminology and basic concepts. In there, we see significant differences, which also prevent a common understanding of the domain and its problems (i.e., various names for properties, e.g., attribute, feature). In addition, (2) nearly all specifications are quite static concerning attributes describing categories and properties (with BMEcat 2005 being the only exception). Finally, (3) we identified a huge gap in PLIB adoption with regard to inter-organizational business processes in pre-order and order management. Thus, besides our detailed data model analysis regarding the definition of dictionary entries, a major obstacle to a wider proliferation of PLIB-compliant dictionaries is formed by missing and/or insufficient specifications regarding the *usage* of dictionary entries.

While the current degree of ISO 13584 adoption is low, other developments exist that either aim at brining PLIB to the real-world or could help improving XML-based specifications. A major effort is undertaken by many consortia in defining PLIB-compliant dictionaries, thus creating dictionary entries. These projects follow a 'push logic', thus if PLIB content is emerging, the need for compliant message specifications will increase. Moreover, recently two standardization bodies have started working on new exchange specifications for catalogs: However, both the Universal Business Language 2.0 [18] and the CEN/ISSS EEG1 Project Team cCatalogue [19] avoided the subject of specifying models for the definition of PLIB dictionaries; though they do implement the GUID concept, thus allow giving ID-based references to entries.

Our findings and conclusions stress the importance of being able to use PLIB dictionary entries in critical, value-adding business processes. In that sense, we regard future developments in ISO TC184/SC4 on standardizing an XML-based exchange format for dictionaries as a meaningful step; this will, however, not address the issue of using PLIB-compliant content in transactional business processes.

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Leading the Web in Concurrent Engineering
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A Standardised Data Model for Process and Flow Management: ISO 15531-43 – A Step Towards CE in Manufacturing –

A.F. CUTTING-DECELLE[1,a], R.I. YOUNG[b], J.P. BOUREY[c], J.J. MICHEL[d], L.C. POUCHARD[e]
[a] *Industrial Engineering Lab, Ecole Centrale Paris, France*
[b] *Dept of Mechanical and Manufacturing Engineering, Loughborough University, U.K.*
[c] *Industrial Engineering Team, Ecole Centrale Lille, France*
[d] *IDPICONSEIL, France*
[e] *Oak Ridge National Laboratory, USA*

Abstract. Ready access to information is a critical requirement in concurrent engineering and access to manufacturing information is particularly important to businesses involved in the product production. While a range of research has considered manufacturing information models for process planning, little has been done to formalize an information model to support process flow information. This is necessary for all areas of manufacture where flow is important including process planning, production planning, scheduling and supply chain management. This paper introduces a new standard which is being introduced to support flow management and discusses the key features which it offers.

Keywords. Process management, flow management, data model, concurrent engineering, standard

Introduction

The information generated about the manufacturing process of an industrial product is very important for the life cycle of this product, notably in a context of sustainable development. Manufacturing may be defined as the transformation of raw material or semi-finished components leading to goods production. Manufacturing management is the function of directing or regulating the flows of goods through the entire production cycle from requisitioning of raw materials to the delivery of the finished product, including the impact on resources management.

A manufacturing management system manages the flow of information and materials through the whole production chain, from suppliers, through to manufacturers, assemblers, distributors, and sometimes customers. The relations among those partners may be identified and structured in an electronic form with a view to facilitate electronic exchanges. Then, information handled during these exchanges have to be identified, modelled and represented in such a way that they may be shared by a

[1] Corresponding Author: A.F. CUTTING-DECELLE, Ecole Centrale Paris, LGI, Grande Voie des Vignes, 92295 Chatenay-Malabry, France; Email: afcd@skynet.be

maximum of partners through the usage of standards for product and manufacturing data modelling [1].

On a day-to-day basis, the operational planning system of the main plant sends orders to the suppliers to ensure the availability of components, sub-assemblies and others such as resources needed to its manufacturing and assembly process. The aim of The ISO 15531 MANDATE standard is to provide a standardised data model for representing manufacturing management data. The purpose of that standard is to facilitate the integration between the numerous industrial applications by means of common, standardised software that are able to represent these three sets of data. This part of ISO 15531 addresses the representation of data related to manufacturing flow and process management, through the development of a data model of the manufacturing flows and processes.

In the first section of this paper, we will outline the need for process based approaches in manufacturing, particularly for manufacturing management. Then, we present the international standardisation context, leading to the development of the ISO 15531 standard. The following parts are focused on the presentation of the part 43 of the standard, and on the role this part could have in a Concurrent Engineering context.

1. Process based approaches in manufacturing management

As computer-aided design and engineering tools have revolutionised product design during the past decade, computer-based tools for production system engineering are revolutionising manufacturing. One of the major problems is still today the lack of software integration and the lack of interoperability among these tools [2]. To achieve this interoperability, information models are necessary and critical to specify common terms and programming interfaces [3]. In the context of an integrated approach of the Enterprise, through different business processes and models, manufacturing management is an important function of production system engineering.

In this context, the development of a process specification for the production and support operations is required to manufacture the product [4], [5], [6]. Data developed during this phase ultimately take the form of directed graphs and/or flowcharts. Nodes in the graphs contain attributes which identify processes and their parameters. Data developed include: process identification (parameters, process resouces, process time. This process is recursive: high level processes are decomposed into subprocesses until all basic or primitive operations are specified. Constraints on groups of processes and operations are identified and precedence relationships are specified.

In the following sections, we propose the example of a process information model: the model developed in the part 43 of the ISO 15531 MANDATE standard.

2. The ISO TC 184 / SC4 development context

2.1. The scope

The scope of SC4 includes all the industrial data related to discrete products including, but not limited to: geometric design and tolerance data, material and functional specifications, product differentiation and configuration, process design data,

production data (including cost), product support and logistics, life cycle data, quality data, disposal planning data [7]. It includes organizational data such as the relationship between enterprises or the relationship between components of a single enterprise for the purposes of supplier identification. It includes personnel data to the extent of identification of approvals. Specifically excluded are business planning data such as profit projections, cash flow, etc., and any other personnel data or organizational data.

2.2. The goals

The goal of SC4 is the creation and maintenance of standards that enable the capture of information comprising a computerized product model in a neutral form without loss of completeness and integrity throughout the lifecycle of the product.

Specific objectives include: flexibility to permit expansion without invalidating existing portions of the standard, efficiency for processing, communication, and storage, rigorous and unambiguous documentation, the minimum possible set of data elements, separation of data content from physical format, a logical classification of data elements, compatibility with other existing relevant standards, implementability, and testability.

3. Presentation of the ISO 15535-43 part

3.1. Main features of the part

This part addresses the modelling of data for the management of manufacturing flows as well as flow control in a shop floor or in a factory [8]. This manufacturing flow model is provided in the context of various processes that run simultaneously and/or sequentially, providing one or more products and/or components and involving numerous resources as indicated in Figure 1. In this context one component may be the input of several processes, one process may provide different components and/or product simultaneously or successively, different processes may make use of the same resource successively. For example, the same component (or raw material) C2 is an input of processes A and F, as well as component (or raw material) C3 for processes F and L. Process A provides components for both processes B and D ; process F provides components for process C, K and G ; process L provides components for processes H and M, etc. that may occur simultaneously or successively. Processes B and C make, successively, use of the same resources, as well as processes G and H with another resource.

This part provides a way to model the data needed to manage the multiple complex flows that have to be taken into account between the different manufacturing processes that run simultaneously or successively in a factory. That includes products, components or raw material flows as well as services flow such as information flows.

Since the universe of discourse of this part is the complete manufacturing processes in a factory, the flows management data under consideration also includes the data used to manage the flows that are coming from the environment of the factory (considered as a system) as well as those that are going to this environment.

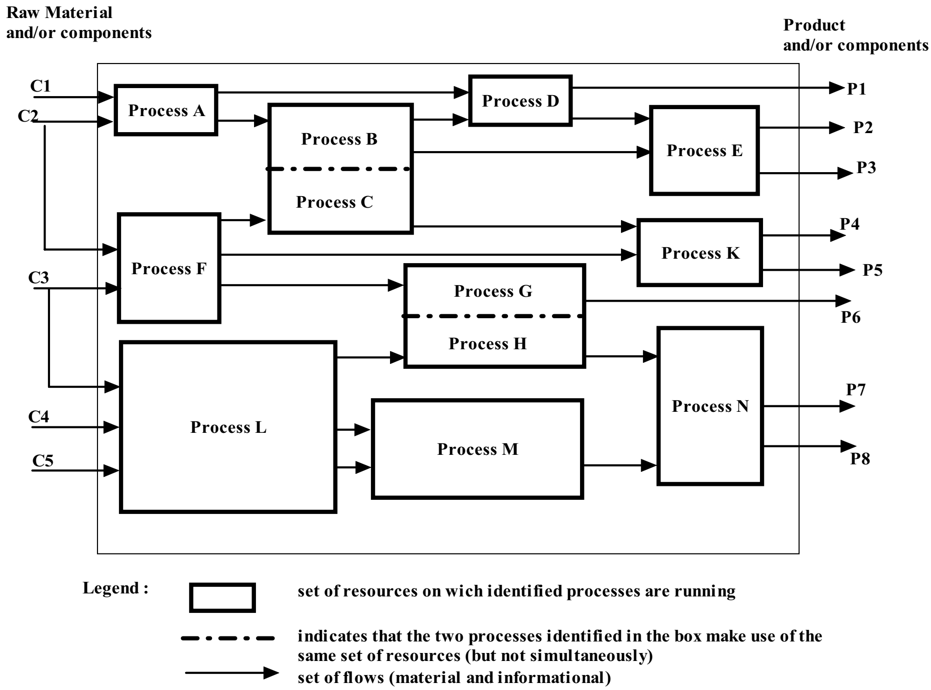

Figure 1. Multiple manufacturing processes in a factory

3.2. Main entities of the schema

The schema of the part is expressed using the EXPRESS language, described in the part 11 of the ISO 10303 STEP standard [9]. We present here the two main entities of the schema (process and flow entities), then its graphical representation, using the graphical representation provided by the EXPRESS language: EXPRESS-G.

3.2.1. Process entity

A **process** is a structured set of activities involving various enterprise entities, that is designed and organised for a given purpose. The EXPRESS specification of the entity is:

```
ENTITY process;

     id: identifier;
         name: label;
         description: text;
         operates_on: process_flow_assignment;
         process_characterised_by: process_property_value;
         starts_at: point_in_time;                -- ISO 15531-42
         corresponds_to: interval_of_time;        -- ISO 15531-42
         uses: resource;                          -- ISO 15531-32
         decomposes_into: SET [0:?] OF process;
 UNIQUE
     UR1: id;
```

```
END_ENTITY;
```

The definition of the attributes is:

- **id:** allows a **process** to be identified**.**
- **name**: label by which the **process** is known.
- **description**: main characteristics of a **process**.
- **operates_on**: **flow**s dealt with by the **process**.
- **process_characterised_by**: **process_property_value** characterising the **process**.
- **starts_at**: **point_in_time** characterising the beginning of the **process**.
- corresponds_to: interval_of_time **characterising the** duration **of the** process.
- **uses**: **resource** necessary for the **process**.
- **decomposes_into:** set of **process**es the **process** is composed of.

3.2.2. flow entity

A **flow** is a motion of a set of physical or informational objects in space and time. The EXPRESS specification of the entity is:

```
ENTITY flow;
       id: identifier;
       name: label;
       description: text;
       corresponds_to: process_flow_assignment;
       flow_characterised_by: flow_property_value;
       classification: type_of_flow;
       decomposes_into: SET [0:?] OF flow;
UNIQUE
    UR1: id;
END_ENTITY;
```

The definition of the attributes is:

- **id:** allows a **flow** to be identified**.**
- **name**: label by which the flow is known.
- **description**: main characteristics of a **flow**.
- **corresponds_to**: **process**es to which the **flow** corresponds.
- **flow_characterised_by**: **flow_property_value** characterising the **flow**.
- **classification**: **type_of_flow** provides a way of classifying different **flows.**
- **decomposes_into**: set of **flow**s the **flow** is composed of.

3.3. EXPRESS-G representation

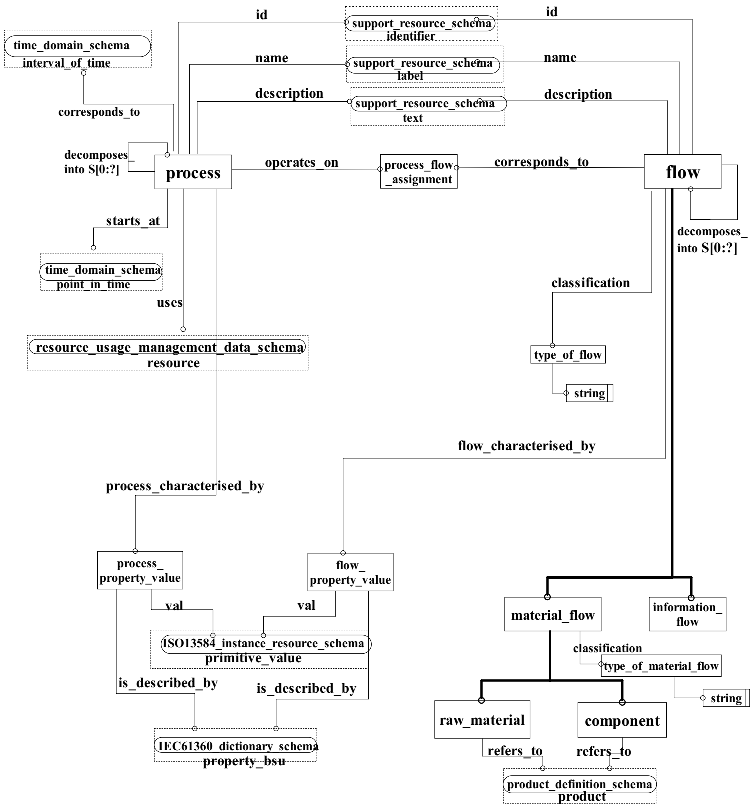

Figure 2. Manufacturing_flow_management_data_schema EXPRESS-G representation

The other entities of the schema are:

- **type_of_flow:** alphanumeric string used for a **flow** to be identified. It does not need to understandable through the natural language.
- **type_of_material_flow:** alphanumeric string used to classify a **material_flow**. It does not need to be understandable through the natural language.
- **material_information**: subtype constraint used to define subtypes of **flow** for which a classification is needed.
- **rawmat_component**: subtype constraint used to define subtypes of **material_flow** for which a
- **process_property_value:** defines the properties of a **process**, by links to the corresponding entities of the ISO13584 P-LIB [10] standard.
- **flow_property_value:** defines the properties of a **flow**, by connections to the corresponding entities of the ISO13584 standard.
- **material_flow:** motion of a set of physical objects in space and time.
- **information_flow:** motion of a set of informational objects in space and time.
- **raw_material:** subtype of **material_flow** characterised by the motion of unrefined or untreated materials.
- **component:** subtype of **material_flow** characterised by the motion of sub-assemblies before they are incorporated into more complex structures.

4. Use of the standard in a CE context

Concurrent engineering has been defined as: " ... a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. [11] is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements" [12].

The emphasis is on developing a comprehensive understanding of all aspects of the product early in the lifecycle.

The primary goal of open systems based on standards is to make application software more portable and interoperable. Portability and interoperability, however, require more than simply the use of standards. It is important to take the special characteristics of software standards into account when designing open applications. Given some of the shortcomings of standards (reflect of an industry consensus at a given point in time ; as innovations are made and spread among vendors, standards must change to reflect what has become new common practice), what is the most effective way of using them to achieve applications portability ?

One approach is to build components that provide services specific to a given use within an industry or an individual organization, resulting in a hierarchy of services: applied to this part of the MANDATE standard, this approach results in:

- the identification of process properties and flow properties applicable ;
- the identification of appropriate resources needed for the process.

Supply chain management can be considered as a typical application of this approach.

It is also possible to specify an application programming interface (API) for a particular industry, for example, food industry, or pharmaceutical industries.

Software systems based on standards can be considered as particularly effective in meeting the following requirements of the Defense Advanced Research Projects Agency Initiative in Concurrent Engineering (DICE), outlined by [13]: high commercial content, standards strategy, commercialization strategy, incremental usability, low maintenance and training costs, high user acceptance and satisfaction.

The use of open systems for concurrent engineering has implications for both the engineering process, and the result of the process: the product. How can systems based on standards affect concurrent engineering? How can they help in meeting the needs of concurrent engineering?

- High commercial content: use of commercial, off-the-shelf software, rather than custom-developed software: with standard software functions available for nearly everything from security, to real-time, to fault tolerance, it is possible to build almost any type of application using open system products.
- Standards strategy: migration path to accommodate changes in standards: accommodating changes in standards can be difficult. It is necessary to mitigate these problems by reducing the dependency of product software on generic standards.
- Commercialization strategy: the use of standards-based application platforms results in major improvements in the ability to market tested and proven software components.. The availability of common API specifications for a wide variety of application platforms greatly broadens the scope of reuse for software components.

- Incremental usability: every application platform in the manufacturing environment benefits from a range of procurement options. Each may be updated using new technology as it becomes available. Standardized APIs present a stable view of the underlying platform to the application programmer (and the software), and isolates them from the rapidly changing technology under the interface.
- Low maintenance and training costs: a concurrent engineering environment that is cheaper to set up and maintain than existing environments. Standard API based software platforms are providing new options across the full range of manufacturing applications.
- High user acceptance and satisfaction: short learning curves and ease of use. Stable, standards-based application program interfaces provide the opportunity to build stable test concepts and technology. Tools and simulation techniques are evolving to make this task much easier.

5. Discussion – issues – conclusion

This paper has discussed the need to capture information representations for manufacture and especially the need to support manufacturing process flows. It has provided formal representations for "process" and "flow" in EXPRESS and illustrated their attributes and relationships in EXPRESS-G.

Significantly this work is a part of the overall manufacturing management support of ISO 15531 which offers a basis from which manufacturing information can be shared across system boundaries; an essential requirement for the ultimate goals of concurrent engineering.

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Information Systems in CE

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Leading the Web in Concurrent Engineering
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A solution for an unified vision of the enterprise informations

Fabien LANIEL [a], Mihaela MATHIEU [a,1] and Jean-Jacques GIRARDOT [a]
[a] *Centre G2I, Ecole Nationale Supérieure des Mines de Saint Etienne, France*

Abstract. Search engines are now tools of every day life, Google being the most famous example. While they allow to access easily Internet documents, they are more and more used, under the denomination of "enterprise search engines", to manage the considerable amount of documents that constitute the memory of entreprises. We present the ground of a search engine that aims to propose a unified vision of the different documents formats (HTML, XML, Word, Mail, etc. but also data from databases) and to make search into these documents transparent to the user.

Keywords. Desktop search, Structures documents, Database, XML, Enterprise search engine

Introduction

The search engine, already an inescapable web surfing aid, is on the way to becoming an essential enterprise tool.

Why should we want an enterprise search engine ? Because we need to make available, selectively if necessary, a part of the enterprise memory to the employees, possibly to some subcontractors, or even to a larger audience[2]: technical or juridical documents, records of previous studies, official notes, memorandums, internal mails, etc. An enterprise search engine should ideally provide each employee with the possibility to access enterprise information, but also to manage his/her own personal data. The best approach would be to provide in a single engine a unified way to access to personal data, intranet and internet. Many softwares that provide a part of these features already exist, like Google Desktop or Exalead [6], or are announced, like MSN. However, none of them provide the full set of services that are needed.

What could improvements in these tools consist of ? Search engines should provide more relevant results, for example by taking into account the fact that a request such as “data structures” is a nominal group, and not the sole words “data” and “structures”, to avoid providing “data about alloy structure” as a potential answer. This implies at least the management of proximity and order relationships which is not implemented in most engines.

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[1]Corresponding Author: Mihaela MATHIEU, Centre G2I, Ecole Nationale Supériuere de Mines de St. Etienne 158, cours Fauriel, F-42023 Saint Eienne cedex 2, France; E-mail: mathieu@emse.fr.

[2]Such a definition implies that we take into account security, confidentiality and access rights problems, which we won’t deal with in this specific study.

It could be useful for a search engine to manage not only the corpus itself, but the user's individual preferences, which could contribute to discard answers that are not significant fort this specific user. Also, a better analysis of a request could determinate which parts are related to the contents, the structure, or others aspects of the document, like for example, the author, the date of creation, filing, or last access to this document. Moreover, any answer should take into account that we often need just a specific part of a document, and not its whole contents.

Ideally, anyone should be able to express precisely all these aspects, even if he/she has no specific knowledge of search engines or computer science. This suggests that natural language should be used for requests, with an analyser that can translate these requests in a specific query language (as proposed by [14]), and a search engine that can manage these aspects.

Integration of heterogenous databases within a large global object database is a well known problem, for exemple, [11]; the solution is techincal and based on a four-layered models. Theoretical complexity of the complete integration problem is studied in [1]. Other approachs compute a middleware database to be used by various applications as Garlic [7].

An other category of integration solutions adresses an universal language for quering heterogenous data: see [10]. Our paper's aim is to built a search engine which integrates all data entreprise: (structured) text documents, mails, databases into a large virtual collection of equivalent XML documents.

1. Various documents formats

In most commercial enterprise search engines, emphasis is largely put on the fact that the system can manage hundreds of different document formats. Actually, the real challenge for the years to come is to extract the pertinent parts of the documents, according to complex criteria. We will focus here on strongly structured documents, which, in the practise, are almost always XML documents, for which request languages likes XQuery or NEXI [14] are suitably adapted.

However, let's notice that there exist, for flat documents (or text only documents, this category including postscript or pdf documents), methods to recognize the implicit logic structure of the document, see [5] for exemple, that can make explicit the structure, and even tools that perform speech analysis and assign specific roles (abstract, exposition, discussion, conclusion, bibliography, etc) to parts of a document. It is therefore possible for the query engine, with such additional knowledge, to return better answers to the user.

Besides these textual documents (that do not change with time, and can be considered as archives), there exists living data in the enterprise, than evolve regularly, and are often kept in traditional or object databases, since they are used by many applications. It seems logical to expect an enterprise search engine to handle at least a part of the information kept in these databases, especially text information. Clearly, not every item of a database is of interest for the user, and he/she may have to specify which tables (and which fields, under which conditions), could be the object of queries. This, in fact, consists in defining specific views of the database, considered interesting, and handle them as virtual tables. Finally, one may want to find precise information in weakly structured documents, like mails or discussions forums, that are also often kept in databases.

All in all, the challenge is to provide the user with a unified vision of every useful information in the enterprise, with an efficient and pertinent access tool.

2. Existing XML search engine

Now we will describe our approche to solve the problem.

We have already developped a search engine for information retrieval for XML documents, based on a relational database [9]. We solve the part of the request concerning the text contents with a TF-IDF method[3] extended to structured documents. The query language is NEXI [14]. This query language is very simple and intuitive, based on the XPath syntax. For example the query: *"//title[about(., US government]"*, refer to documents whose titles speaks about the American government.

We added in our system a relevance ranking system, based on two proximities:

Physical : words are physicaly near.
Structural : words are in the same segment of the document, or in segments that are hierarchically close to each other.

We won't explain the reasons why we devised the database organisation; we will only describe this organisation and how the information of the XML documents are stored in the database. The interest of this diagram is that it does not impose any restriction, neither on the DBMS used, nor on the DTD nor on the Schema of XML documents.

Corpus Table

This table is used to store the $name$ and the url of each indexed file. For each file we assign it a unique identifier $FileID$. This identifier is the primary key of the table $Corpus$.

Vocabulary Table

This table contains all the words of indexed documents. For each word, or $token$, we assign a unique identifier $tokenID$, and also a $type$ allowing to differentiate the words, concepts or other types of phenomena specific to various sciences, technology or disciplines. The primary key of this table is ($token$, $type$); $TokenID$ being a potential key.

Node Table

This is the table which contains principal information on the contents of XML documents. We will first remind the reader that an XML document can be seen as a tree in which words are leaves, and structures are internal nodes.

From this tree we can number each node with two values : $begin$, the number of pre-order of this node in the tree and end, the maximal value of the $begin$ among the elements of the sub-tree rooted in this node.

The $begin$ value is a "unique" identifier of an element in a specific tree, the couple of values ($begin$, end) allows to know quickly if an element is contained in another. We also store for each node the identifier of the file in which it appears, the identification number of its father, of its next sibling and his first son (in order to accelerate requests solving). Leaves, of course do not have sons, so the field end can indifferently be set to 0 or ϕ). The primary key of this table is ($FileID$, $begin$).

[3] see [3] for a formal définition of this method and [4,13] for some extentions

NAME	ADDRESS1	ADDRESS2	ZIPP	CITY
Courbon	rue Berlioz		42000	ST ETIENNE
Usinor	rue des Rosiers		88000	MEUDON
Locatim	lieu dit Les Tours		14050	RODEZ
Usinor	bd Auguste	Bât Val fleuris	42100	ST ETIENNE

Table 1. A table of a Database

Attribut Table

This table is used to store the attributes which are associated with each structure of XML documents, and the type in XMLSchema. For each attribute we keep the file in which it appears ($FileID$) as well as the structure that contains it ($structure$), the name of the attribute (which is also a reference to table $Vocabulary$), its value and its XMLSchema type. The primary key of this table is ($FileID$, $structure$, $TokenId$).

Many approaches of representing XML documents into databases have been proposed; we can see [2] for an exhaustive description. The organization proposed here allows the representation of heterogeneous corpus, and facilitates the effective access to the data within the framework of information retrieval.

3. Integration of informations from Databases

The (R)DBMS provides for complete and elaborated mechanisms to manage user rights to access or use informations contained in the database. Our search engine don't provide any management system for users and their rights. We have the same problem for the informations from textual and structured documents. However, as explained earlier, our focus is only information retrieval, and we imagine that no confidential, or supposed as such, informations are integrated in our system.

So we consider that whole tables from database are interesting and our search engine must index them. The table 1 shows an example of a database table.

An ingenuous approach would be to build an XML file from the initial database and to integrate it after in our search engine (see figure 1).

This solution is not acceptable, because the informations would be stored into the initial database, into the index of search engine and also into the XML file. Moreover, with such a solution, we must pass on some information about this file to the search engine, and some problems could appear while updating databases informations.

However we have defined a very simple XML format for informations transfer from the initial database. But such a file will never be built and stored explicitly. The tags of this XML document are named as the names of databases, tables and fields. Inside an XML element representing a database we will store all the informations from this database. Inside an XML element representing a table we will store a row of this table. We will have as many tags $< table >< /table >$ as rows into this table. Inside the XML elements representating a field we will store the column of the table.

We show now how the index of our search engine is fulfill, i.e. the tables $Corpus$, $Vocabulary$ and $Node$. The table $Attribute$ is not used, because the XML conversion file doesn't contain XML attribute. For each analyzed database we store a row in the $Corpus$ table, this row contains the location of this database. See following for the row corresponding to our example :

```
<SAV>
  <CUSTOMER>
    <NAME> Courbon </NAME>
    <ADDRESS1> rue Berlioz </ADDRESS1>
    <ZIPP> 42000 </ZIPP>
    <CITY> ST ETIENNE </CITY
  </CUSTOMER>
  <CUSTOMER>
    <NAME> Usinor </NAME>
    <ADDRESS1> rue des Rosiers </ADDRESS1>
    <ZIPP> 88000 </ZIPP>
    <CITY> MEUDON </CITY>
  </CUSTOMER>
  .....
  <CUSTOMER>
    <NAME> Usinor </NAME>
    <ADDRESSE> bd Auguste </ADDRESS1>
    <ADDRESS2> Bât Val fleuris </ADDRESS2>
    <ZIPP> 42100 </ZIPP>
    <CITY> ST ETIENNE </CITY>
  </CUSTOMER>
</SAV>
```

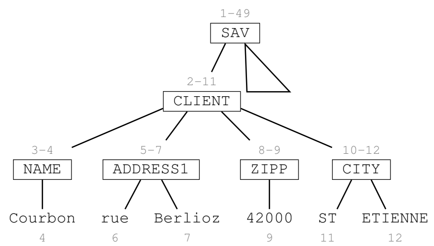

Figure 1. The XML file corresponding to our database example

TokenID	terme	type
x	SAV	DB
x+1	client	table
x+2	NAME	field
x+3	ADRESSE1	field
x+4	ADRESSE2	field
x+5	ZIPP	field
x+6	CITY	field
x+7	Courbon	word
x+8	rue	word
x+9	Berlioz	word
x+10	42000	word
x+11	ST	word
x+12	ETIENNE	word
x+13	Usinor	word
x+14	...	word

FileID	debut	fin	TokenId	père	fils	frère
f	4	ϕ	x+7	3	ϕ	ϕ
f	3	4	x+2	1	4	ϕ
f	6	ϕ	x+8	5	ϕ	7
f	7	ϕ	x+9	5	ϕ	ϕ
f	5	7	x+3	2	6	ϕ
f	9	ϕ	x+10	8	ϕ	ϕ
f	8	9	x+5	2	9	ϕ
f	11	ϕ	x+11	10	ϕ	12
f	12	ϕ	x+12	10	ϕ	ϕ
f	10	12	x+6	2	11	ϕ
f	2	12	x+1	1	2	ϕ
f	15	ϕ	x+13	14	ϕ	ϕ
...	...	...	...	...	...	...
f	1	49	x	ϕ	2	ϕ

Table 2. Rows inserted into Vocabulary table and rows inserted into Node table

FileID	file	URL
f	base_SAV	mysql:193.90.90.90:1541

Into the $Vocabulary$ table we store the tags and the words contained between these tags, i.e. the text of the fields. This text is parsed. We store for the names of databases, tables and fields tag, with an explicit type: `DB`, `table` or `field`. If there are into the database a table and a field having the same name, two rows will be inserted in the $Vocabulary$ table with different values of $TokenID$ and different types (`table` and `field`, respectively). If there are into the database two tables having fields with the same name, only one row will be inserted. The table 1 show the rows inserted into $Vocabulary$ table, according to our example.

Note that representing the content of a database into an XML format introduces artificially a supplementary constraint into the generated document and there isn't any order relation between the tables of a database, nor between the fields of the same table. This is not a really important problem; in our XML file only the direct descendant relations are important, i.e. father - son relation; these relations translate the membership of an element tagged with a table name to the database who contains this table and the mem-

Question :
`"Usinor"`

Documents :
- file://General/Société.xml
- file://Web/SAV.html
- file://Rapport/12_9_2005.doc
- file://Web/index.html
- ...

Database
- SAV.CLIENT :

NOM :	Usinor
ADDRESS1 :	rue des Rosiers
ZIPP :	88000
CITY :	MEUDON
NOM :	Usinor
ADDRESS1 :	bd Auguste
ADDRESS2 :	Bat Val fleuris
ZIPP :	42100
CITY :	ST ETIENNE

Figure 2. Answer for a simple query

bership of a value of a field to a row. So we force to the null values the content of the *brother* fields. The *Node* table can be built easily : we start inserting the node corresponding to the leaves. We are able to calculate also the values *begin* and *end* for each intermediate node. See table 1 shows the rows added to this table, corresponding to our example.

It's obvious that the search engine never get only the value of a field as a response. If the result of a query has the type *field*, the search engine gives as response the whole row containing this field (by getting up into the tree to the structure of type *table*). If the result has the type *DB*, the search engine gives only the name and the location of the database, but not its content.

4. Examples

We describe two examples of requests. These examples are very common and easy to understand (they are expressed using keywords or natural language).

Example A

Imagine that we seek information about *Usinor*. It is enough to provide the word. The request in NEXI would be: `"Usinor"`. In this case we seek in the table *Vocabulary* the *tokenID* associated with the word *Usinor*. Then we carry out a research in the table *Node* to find all the occurrences of this word.

For each of these occurrences, we recover the encompassing structure, which may enable us to group multiple occurrences of the word *Usinor* within the same structure. If the type of the father structure is *field* we proceed as explained in the preceding part.

Now we can return to the user documents referring to *Usinor*, sorted by relevance, as well as the records contained into the database of the company (see figure 2).

Example B

Let us treat a more elaborate case, such as: *"I would like to get the address of the USINOR factory of St-Etienne"*. A translation of the natural language towards NEXI [12] can

file://Mail/docA.xml

```
<letter>
  <dest>
    ...
  </dest>
  ... whith the company Usinor ...
  ... congress in St-Etienne ...
</letter>
```

file://Mail/docB.xml

```
<letter>
  <dest>
    ...
    Usinor, St-Etienne
    ...
  </dest>
  ...
</letter>
```

Figure 3. Some examples of documents

Question :
`//*[about(.,Usinor) and about(.,"St Etienne")]`

Documents :
- file://Mail/docB.xml/dest
- file://Mail/docC.xml
- file://Mail/docA.xml
- file://Mail/docD.xml
- file://Web/index.html
- ...

Database
- SAV.CLIENT :

NOM :	Usinor
ADRESSE1 :	bd Auguste
ADRESSE2 :	Bat Val fleuris
C_P :	42100
VILLE :	ST ETIENNE

...

Figure 4. Answer for a more elaborate query

produce[4] the request :
`//*[about(.,Usinor) and about(.,"St Etienne")].`[5]

Let's have a look to the folowing documents of the figure 3.

Even if these four documents are potential results for the NEXI request, because of the proximity of the words (physical and structural), the document *docB* is considered to be a better answer to the request. We can also notice that in the case of this document the answer is only represented by the sub-structure *dest*, and not by the whole document as in the other documents.

In the case of the database, only one record answers exactly the request; the others have just one part of the elements of the request.

With these criteria it is possible to provide the user answers sorted by order of relevance, see figure 4.

5. Prospects

Our first search engine has been tested on different corpora, and very promising results were obtained for textual and structured documents [8] . We are currently developping and testing the integration of the structured documents resulting from the databases. We will measure the performances for various types of documents: textual or resulting from the databases.

This search engine will have naturally its place in a network architecture as an enterprise search engine or a web gate, but also as an interface to public databases. Very large

[4] Several translations may be proposed for a request, generally, because of ambiguities of the natual language

[5] In this example, we voluntarily do not introduce any specific knowledge about the database. In this case, our system of analysis cannot use the concept of address, and does not hold account of this element for the request. It would be possible to add in the system [12] the knowledge that the concept addresses is incarnated by fields ADRESSE1, ADRESSE2, ZIPP and CITY, so the system would answer more precisely to the query.

data bases are integrated in our information retrieval system without major drawback, this system strores textual rather numerical information and every word is stored only once into the index.

6. Conclusion

We have presented the prototype of an enterprise search engine, proposing several innovations:

- Representation of its data in a relational database, allowing us to benefit of all the developments carried out in the field.
- Capacity to index flat, semi-structured or structured documents, but also information represented in the database of the company.
- Use of queries in natural language, offering to any user a very great flexibility of expression, without any preliminary training.

The whole set of these original characteristics defines a new category of product, being able to render invaluable services, as well as an individual tool for each employee of an organization or as a web gate, by offering a convivial and relevant access to the data that a company wants to make available.

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Secured Information System for Concurrent Engineering Applications

Florin HARTESCU
National Institute for R&D in Informatics
8-10 Averescu Avenue, 71316 Bucharest 1
Romania
E-mail: flory@ici.ro

Abstract. The paper presents a sustainable business model for open source software tools, managing and disseminating documents in heterogeneous software (source code files, database objects, graphical objects, text files etc) for concurrent engineering applications.
The paper motivates the utilization of open source models for the maintenance and adaptation of the application or generic software. It describes the representation of the software in Internet computing, the architecture of the open source-based XML repository manager and the most important issues for its implementation.
The system uses encryption and other security mechanisms to ensure that only authorized users can access a concurrent engineering application and the data cannot be intercepted.

Keywords. Secured systems, simulation, process control, optimisation, control of distributed parameter systems, open source, concurrent engineering, collaborative networks

Introduction

One of the enterprises problems is the lack of interoperability of software applications to manage and progress in their business. Enterprises are looking for new business relationships, and the exchange of information and documents with new partners often cannot be executed automatically or in and electronic format. This is primarily due to problems of incompatibility with the information representation adopted by the software applications they are working with.
The Open Source movement has developed new concepts of making business based on transparent and co-operative ownership of software. The system develops methods and tools to better match the results from the F/OSS software designers community and potential users in collaborative networks in various businesses in an unprecedented way.
A conceptual model is an abstraction for computational realisation of a world of entities (e.g., physical, concept, relationship, method, constructor, fact, rule).
The system presented brings together relevant software and technology demonstration in this field and tackles the following issues:
1. Motivations and sustainable business models for open source software provision
2. Co-operative design models for authentication to various enterprise services
3. Developing and integration of mission critical applications for enterprises
4. Reference implementations for open groupware and multimedia archiving solutions
5. Simplification and visualization of F/OSS legal aspects and licensing

1. The System Aims

The interoperability in enterprise can be defined as the ability of enterprise Software and Applications to interact.
The system aims at a series of activities to apply this scheme to different types of business areas, especially for SMEs and NGOs in collaborative networks. The overall goal is to foster the usage of F/OSS backend platforms and services and to generate new business opportunities for the Open Source developer community. The open source-based set of tools is supposed to have a high socio-economic effect for both, the providers and users of F/OSS, with a special focus on SMEs. On the development side, the system is arranged around a few models, bringing experience and moderating integration to various end users.
Scientific and technological objectives and state of the art of the system supports the migration of the business processes in enterprises and public organizations to use F/OSS. A number of F/OSS solutions are available for different purposes, however some elements are missing so that F/OSS can be used for supporting all day-to-day business tasks.
The Open Source movement has to tackle some obstacles, in order to be competitive with commercial closed license solutions. First, a few critical applications in the area of accounting, customer relation management or shared calendaring are not available or need major improvements. Secondly, many mature F/OSS applications, which are already used in offices, such as file sharing, forum, web mail, or web logs, usually have different user management schemes, which enforce the user to remember different user names and passwords.

2. General Presentation

By splitting the application across three tiers, we are able to separate out the three logical components of the system : user interface, computational logic and data storage. Each logical unit can then be developed separately from the others, introducing an important degree of flexibility into the design of the application.
The open source-based set of tools provides a mechanism for tight integration of authentication schemes of various enterprise related applications to a commonly managed user base. The experience in ISP hosting business shows, that it is not wise, to give any user his own account to access different kind of services due to security risks. Instead, the product manages user accounts in a database and makes it available through various interfaces (including LDAP) and programming languages. This provides high flexibility for user and group management and minimizes the risk for exploits.
The system provides enterprises with reliable business applications, which seamlessly work together, and makes any office independent from closed source software.
The long-term impact of Open Source business applications is that it radically simplifies and standardizes servers in any companies big, medium or small data center. Because Linux runs as well on low-cost Intel as it does on high-reliability mainframes, Linux brings consistency and manageability to the data center. This makes Linux a key technology that will transform today's garbled, underutilized data center into a highly automated resource built on cheap hardware components, an architecture named "Organic IT." Unlike today's data center, in which it can take months to deploy an application, an organic IT data center running Linux can deploy the same application in days.
The system outlines a work programme and vision that leads to the development of:
- a framework platform for service deployment;
- an office server platform;
- tools to help developers build services and applications to be deployed on this integrated platform.

This is highly relevant to the strategic objective by producing open source components, by producing an integrated platform built using these components (to enable further innovation

in the applications and services market), and by producing tools for designers to use to develop applications and services targeting this platform. A key feature of the platform is that is not simply an abstract middleware platform but an instantiation of such a platform in a real-world domain where there is a great demand for new innovative services (essentially hybrid Internet and office services potentially sharing resources from these two domains). At the heart of the system vision in this area is the use of IETF and W3C standards. The system sees this as being of relevance to all future business related services, especially those targeted at networking capabilities.

PHP Web applications for collaborative networks commonly make use of some objects to perform tasks such as connecting to databases or sending email. When moving websites between Web servers, it is critical to know which objects are used on the site, as it may be necessary to install these objects on the new web server or to rewrite the code. The system looks for the instantiation of such an objects through the use of the CreateObject and Server.CreateObject functions. The report produced by the system contains a list of the objects used.

3. Architecture and Platforms

The interoperability in enterprise can be defined more simply as “the ability of enterprise Software and Applications to interact”. Consequently, the objective of Architecture and Platforms for interoperability is to identify generic features, define generic principles and patterns to design interoperable solutions. These design principles and patterns should be independent of technologies and methodologies, and apply across SME’s sectors.

The hardware platform used as a support of the application programs is a personal computer with a Pentium IV processor, 1024 Mb RAM, 512 bits video graphic accelerator, SCSI 80Gb HDD, data acquisition card, one multiplex for 16 serial ports and a network of PLC-s (Programmable Logic Controller). On this machine we have used Unix operating system. This system offers multitasking facilities for parallel managing aspects regarding data acquisition, data transmission, adjusting and data displaying. Using multitasking in collaborative networks we could manage more control loops on the same computer even though some of the processes are controlled only by PLC-s.

The development platform used was Visual C++ 4.0 because it can compile programs for Unix operating system and it has the following facilities:

- Permits creation of separate threads with different adjusting algorithms for each of the processes.
- Offers communication methods inter-threads for transferring data between data acquisition processes and controlling processes. Communications are made using sockets, message boxes and critical sections.
- Permits realization of communication modules in a TCP/IP network. That makes possible implementation of the hierarchical architecture.
- Offers the possibility to create a user-friendly interface for the product, in Unix and Windows environment.

The only disadvantage of this platform is that it hasn't any dedicated functions for complicated mathematical calculus needed in adjusting algorithms, so that we had to write them ourselves.

4. Conclusion

Implementation of this system in Romanian firms has the following advantages: obtaining a high efficiency and time saving, limited efforts for developing a new application in a short

period of time and high performance of the system in solving the demands of collaborative networks for SMEs applications.
The system uses secure socket connections (SSL) to transmit all sensitive information during confidential process.
The application has been tested in an integrated system, with several servers running Windows 2000 and Linux, connected in a collaborative network. The system was configured easily, and it has worked very fast because the communication protocol transmits just the information needed.
The system targets cover three areas.
- Content engineering: is a cooperative task of experts in the domain of SMEs management and information specialists from the IT and multimedia domain. Their outputs are digital modules, consisting of the combination of the management methods, realized by advanced IT solutions.
- Platform engineering: generate the technical framework, supporting the management process and e-business. The platform engineering is based on available standards and methods and executed by integration of IT specialists and IT solutions.
- Business engineering: is a collaborative work, which integrate all the activities of the management and IT professional partners. The target of the business engineering is to offer new management solutions, via the modern methodology and technology.
The system uses encryption and other security mechanisms to ensure that only authorized users can access the collaborative network and the data cannot be intercepted.

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Non Invasive, Cross-Sector Development and Management of Trends

Tobias VALTINAT[1], Wolfgang BACKHAUS[2] and Klaus HENNING[3]
Center for Learning and Knowledge Management and Department of Computer Science in Mechanical Engineering (ZLW/IMA), RWTH Aachen University, Germany

Abstract. AsIsKnown is a project funded within the Information Society Technologies (IST) Priority of the Sixth Framework Programme (FP6) of the European Commission. AsIsKnown represents a system especially designed for a non invasive, cross-sector development and management of trends. The aim is the simultaneous and independent use of information about cross-sector product combination trends by different producers of home textiles.

Keywords. Cross-sectional trends, home textiles, simultaneous trend configuration

1. Introduction

AsIsKnown is a project funded within the Information Society Technologies (IST) Priority of the Sixth Framework Programme (FP6) of the European Commission. The overall aim of the IST project AsIsKnown is to develop a showcase for an integrated knowledge and content flow system between customer, trade facilities and producers through semantically-enabled Knowledge Technologies. This showcase will be exemplified by the home textiles industry.

The business environment in the global home textiles market is becoming even more competitive with regard to the elimination of quota restrictions on textiles and garments since January 2005; coming along with an increasingly presence of Asian products on the world market. Furthermore the European home textiles industry is poorly positioned to compete against Asian countries on a cost basis with regard to a significant relocation of manufacturing to low-wage countries. Hence, the European home textiles industry, an industry dominated by a vast majority of SME's (37.000 companies employ about 1.1 million people), has to develop concepts of dynamic, innovative, multidisciplinary knowledge-based, flexibly integrated and customer oriented networks of businesses to maintain the position of the number one world exporter with an annual export worth more than €20 billion and an annual turnover - not including clothing products - of €106 billion [1].

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1 Dipl.-Inform. Tobias Valtinat: Research Assistant, Center for Learning and Knowledge Management and Department of Computer Science in Mechanical Engineering (ZLW/IMA), RWTH Aachen University, Dennewartstrasse 27, 52068 Aachen, Germany; Tel: +492418091140, E-mail: valtinat@zlw-ima.rwth-aachen.de.

2 Wolfgang Backhaus M.A.: Research Assistant, ZLW/IMA, RWTH Aachen University.

3 Prof. Dr.-Ing. Klaus Henning: .Head of department, ZLW/IMA, RWTH Aachen University.

As in any other trend-related industry it is an ever-moving target for the home textiles industry to continually change course to keep pace with shifting consumer fashions and shopping trends. Much as humans like to wear textiles in the form of clothing on their body they also like to use textiles to make their homes, offices, hotels, restaurants, cinemas, airports and many other private and public buildings more comfortable and aesthetically acceptable. Thus, a great part of creative innovation in home textiles is non-technological in nature. It consists in new combinations of existing materials, designs, patterns, structures, colours etc. to derive a novel product. However, due to the absence of easily measurable success criteria for a new design prototype, compared to functional criteria for a technical product, design can be as risky, time-consuming and costly as research or technological development [2]. But fragmentation and general lack of (financial) resources is certainly the number one problem of the European home textiles industry. This leads to a duplication and discontinuity of research efforts. Players are not connected and act more like “knowledge barriers” instead of working as “knowledge brokers” [3]. At present the European home textiles industry produces 60 % commodity surplus with regard to misinterpretation of future trends in this branch.

Therefore a consolidation of existing research structures and targeted development of newly required expertise and services seems inevitable in the European home textiles industry. AsIsKnown will create a common knowledge base for the European home textiles industry to improve the innovation ability through collaborative engineering and product development in clusters and networks by sharing and (re)using trend-knowledge across multimedia applications with semantic-based collaboration services. These services will enable trend-related industries like the home textiles industry to bring jointly harmonised trend lines on the market by providing a base for a joint decision support and collaborative use of trusted knowledge between different organisations.

2. The workflow of AsIsKnown

The starting point of the workflow of the AsIsKnown system is to collect the product data of different European home textile producers in one system for customer consulting, ordering and overall analysing of customer behaviour. The first step will be to collect the product data of different home textile producers (patterns, colour, quality data, prices etc.). This data will be prepared and unified for further usage in step two. Therefore the semantic web service “Smart Profiler” will be implemented to sample configurations based on the producers’ data in order to develop “style worlds”. These “style worlds” represents whole living environments (living room, dining room, bedroom etc.) assorted of products of different players in the home textiles industry based on proper styles. This will be realised through a non invasive approach which means that the IT systems of the engaged producers should not be modified much. The home textile producers (e.g. carpets, furnishing, curtains) provide their various product information to the “Smart Profiler” which acts as a mediator between different knowledge bases and knowledge-intensive tasks within the business process by providing a common data format for design processes of home textiles. It unifies and prepares the producers data using a common sense ontology (a European language

framework for the home textiles industry) [4, 5]. This will enrich high quality annotations of raw data within this branch.

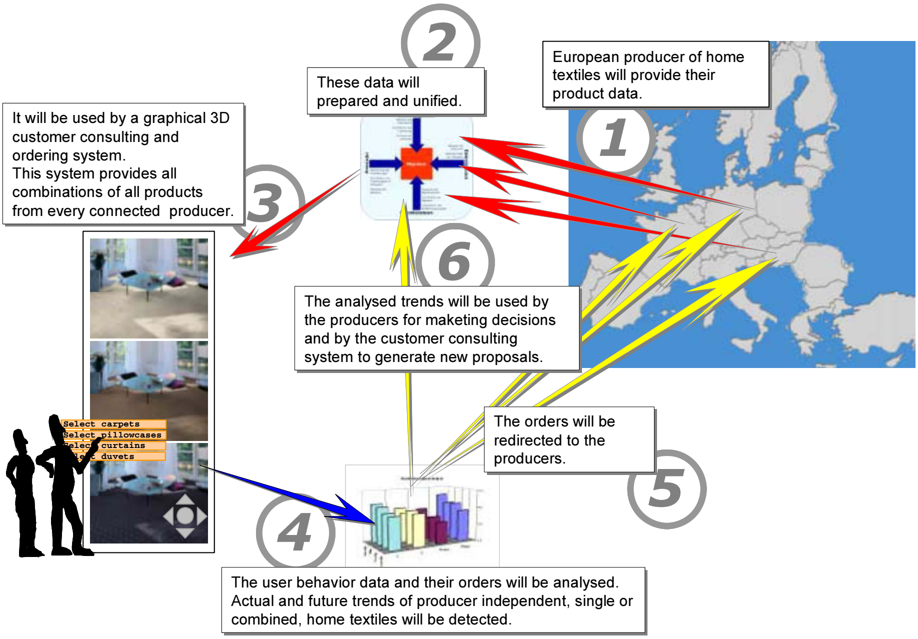

Figure 1. The AsIsKnown workflow (own graphical representation)

In the third step, these data will be used in a customer consulting and ordering system named "Virtual Interior Designer". The "Virtual Interior Designer" is a customer consultant system which presents the producer-independent "style worlds" of different home textile products (in a 3D environment). This virtual front end service of the AsIsKnown system receives orders and records the customer behaviour during their decision process. The orders and the customer behaviour data will be collected by a "Trend Analyser" in the fourth step. The "Trend Analyser" analyses the received data to detect producer independent trends in the European home textile sector. The "Trend Analyser" is a tool suite to support marketing staff in the home textiles industry which, together with the "Smart Profiler", will integrate data across the industries' organisations. Trends and combinations are detected and evaluated by a human expert aided by text and data mining tools. After detecting and validating a trend the expert formulates this trend and / or combinations using a rule editor based on the common-sense ontology. The text mining and data mining components are explorative which means they are heavily knowledge- and experience-based and use a process of creative knowledge discovery. These components support analyses of current market trends which come from the trade press through a News Repository which will keep the database alive with new information from the textiles industry. The marketing staff explores and derives new combinations and trends. These trends are also based upon market news and events in the news.

The results from the "Trend Analyser" will be made available to the producers marketing departments. All information of the "Trend Analyser" will also be transferred to the "Virtual Interior Designer" via the "Ordering database" and the "Smart Profiler". Thereby the "Virtual Interior Designer" will be able to deliver targeted, up-to-date design proposals to the customer. Every mouse click and data entry from the front-end web-service of the "Virtual Interior Designer" will also be fed into the "Trend Analyser" via the "Ordering database". The orders and the results of the analysing process will be redirected to the different producers as well as to the "Smart Profiler" to generate new style worlds (fifth and sixth step).

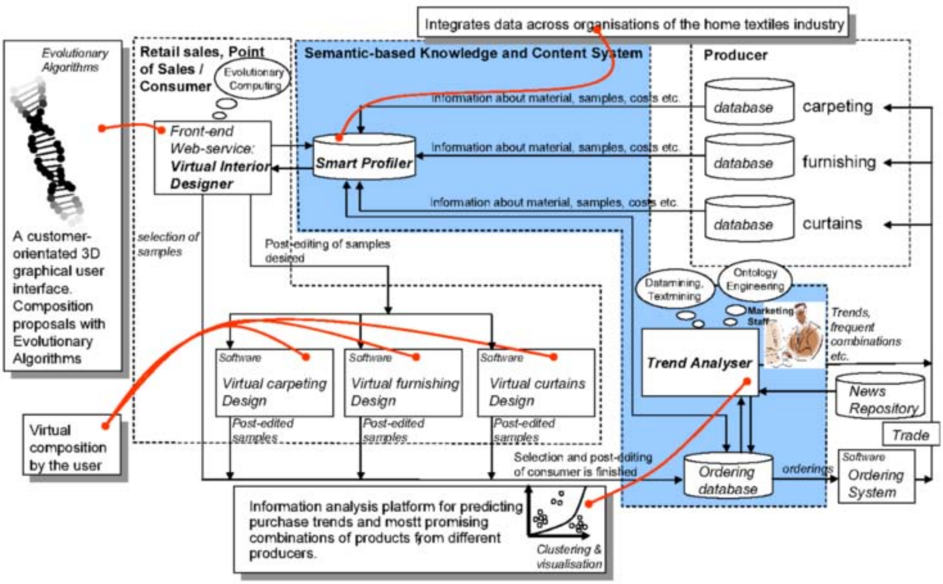

Figure 2. The IT-framework of the AsIsKnown system (own graphical representation)

By means of the AsIsKnown system various trends emerge as a result of the combination of products from different sectors of the home textile industry which can not be individually handled by one sector solely. Furthermore AsIsKnown provides the customer with more choice. Now, he not only has the opportunity to make desired combinations of products by different manufacturers before even buying them, but gets suggestions for other possible combinations. An internet shop ("Virtual Interior Designer") provides an opportunity to combine all the desired choices from different home textile sectors and observes the customer behaviour by web tracking. The manufacturers of the home textiles benefit from the customer behaviour which is helpful in the determination of new combination trends. Different sectors of European home textiles industry can then simultaneously work independently with these trends and concentrate on the production of the textiles on demand (see Figure 3).

The AsIsKnown system supports a knowledge intensive task like designing home textiles - which is a much more personal and cultural capacity - across organsiations of the European home textiles industry. A collaborative design for home textiles regarding the satisfaction of consumer demand for creative, aesthetic goods (harmonised living

environments) requires highly specific, quantifiable and reliable information and knowledge on home textiles, market development and consumer behaviour, which will be delivered through the AsIsKnown system and will be shared across organsations within the European home textiles industry.

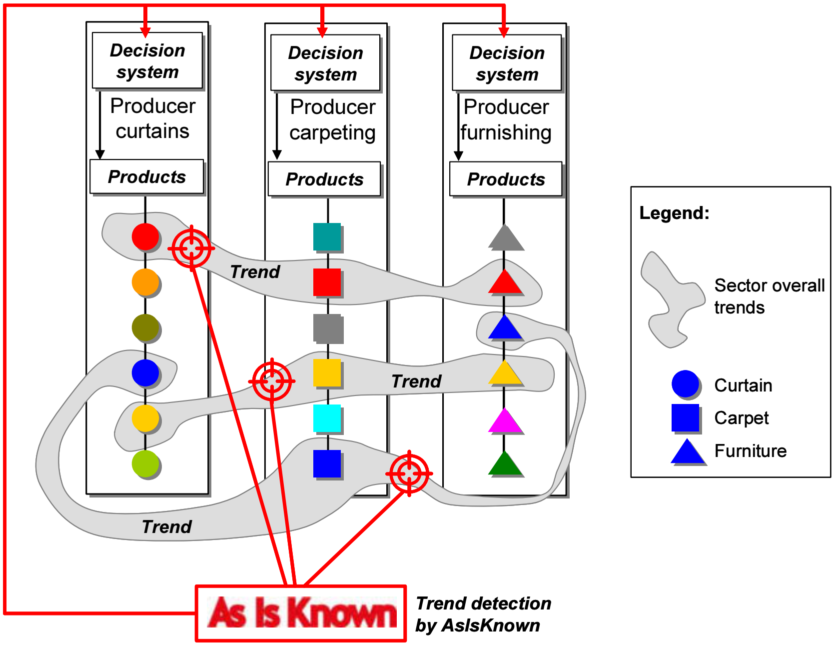

Figure 3. Sector overall trend detection by AsIsKnown (own graphical representation)

Scenario of the AsIsKnown system in operation

A French interior designer wants to plan the interior for a new German luxury hotel complex. Her task is to equip five suites with a given cost limit per suite. Her contractor prefers a rather traditional style. She starts the "Virtual Interior Designer", the front end service of the AsIsKnown System. First she is asked for her preferences and limitations in order to customise the presented offers. Details about the place where the textiles will be used have to be given in order to classify e.g. quality demands on the different textiles. Then she is presented different style worlds, compiled of home textiles namely carpets, curtains and furnishings. The interior designer chooses one of the suggested style worlds. In the selected style world she decides to take the offered curtains and furnishing. She asks for alternative suggestions for carpets, which fit to the curtains and furnishings already selected.

She finds a suitable carpet and orders the chosen elements. With the help of the system she succeeded to furnish the suites according to her customer's limitations in a rather short time. The interior designer orders the chosen elements. On the one hand, the order is transferred separately to the different companies. On the other hand, the ordering is analysed together with former orderings, the user's activities and market news. The results - trends and frequent combinations - will support the generation of new style-world-suggestions.

The results will also be used by the marketing staff of the home textile producers involved. This will support a faster reaction by producers through access to direct information about customer needs. Moreover, the producers are enabled to offer their products in combination with products from other producers, tailored to the needs and limitations of the customers.

3. Potential Impact for the European home textiles industry

As a result of changing market environments the home textiles industry must follow closely changes in consumer trends. As part of the strategy of AsIsKnown all efforts by using latest state-of-the-art techniques to spread and present products and services through different mediums will be maximised. Thus, in the future, the home textiles industry will therefore make use of semantic web services in order to foster market presence.

AsIsKnown leads to an integration of the Semantic Web into the (home) textiles industry. This will accelerate the change from a resource-based industry into a more knowledge-based industry. In the project AsIsKnown collaborative semantic web services for easier and efficient information and knowledge creation, sharing and transfer will be developed [6]. Knowledge will be captured from raw, multimedia and web content by modelling of dynamic knowledge from data integration of the databases comprising the involved producers and the intermediary with collections represented in multimedia entities (images, graphics, 3D objects, video, segments etc.). This will be realised through semantic annotations of integrated "style worlds" appropriate to occasions based on a "common sense ontology" of the European home textiles industry. An important contribution will be the multilingual terminology and gazetteers and their mapping of the ontology. The developed ontology will be based on the existing standards in the domain of the home textiles industry. Through deriving annotations out of the semantic-based services the "Virtual Interior Designer" will develop new style worlds based on the trends delivered by the "Trend Analyser". The "Trend Analyser" will be based on an ontology transferred from multimedia collections (data driven approach). Thus, AsIsKnown is characterised by a thorough combination of state-of-the-art research and new pioneering research activities in various IT fields (ontologies, semantic web applications, data processing, combination and linking of different databases)

But the main innovation is the idea of AsIsKnown itself: the complete support of a novel inter-organisational business process for the European home textiles industry via the use of semantic web components. The data and information allocation gained systematically and stored by the IT tools "Virtual Interior Designer", "Trend Analyser", "Ordering database" and "Smart Profiler" goes far beyond today's possibilities. It allows a revolutionary link between consumer and sales organisation which will be given the opportunity to work with holistic real-life environments in contrast to single product lines. The data from AsIsKnown can be compared to macro-statistics which allows new scope for the interpretation of market developments and potentials. AsIsKnown provides the European textile industry with an important system which enables to generate harmonised trend lines quicker – approved by the customers - and thus shorten the time-to-market with less miss-production due to improved knowledge

about customer needs. Therefore the right product can be delivered to the right place at the right time – a decisive argument for buying European textiles.

AsIsKnown represents a long-term ambition of a new paradigm of customisation and personalisation to end the era of mass manufacturing of commodity products in the European home textiles market. More customer orientation by using and developing further recent content and knowledge technologies for better capturing, exploiting and managing customer needs and preferences is of high economic value for the home textiles industry, because textile based consumer goods not only serve functional purposes but often play a mayor role in the personal identification.

Furthermore, the customisation of textile-based goods is a "path" to fight against counterfeiting and product-piracy which not only have impact upon multinational companies but also on small and medium enterprises in the European (home) textiles industry. The switch from mass-production to customisation across the European industry is one of the long-term development strategies of the "European Technology Platform for the future of textiles and clothing".

4. Conclusion

AsIsKnown provides an industrial showcase for a semantic-based knowledge and content system for several services within the home textiles industry as the envisaged prototypes support the acquisition, modelling, sharing and use of sectoral information and knowledge. The Trend Analyser of AsIsKnown will enable trend-related industries like the home textiles industry to quickly bring products to the market which match jointly identified and harmonised trend lines. This is done by providing a base for a joint decision support and collaborative use of trusted knowledge between different organisations across the supply chain. Thus, knowledge intensive and information-bound tasks and sectors like customer integration, collaborative designing and manufacturing as well as market analysis and e-business will be supported.

A vision for AsIsKnown is the example of the automotive industry as a classical industrial branch which has already adopted ICT to individualise products. The idea is to give opportunity to the customer to choose an individual car (colour, engine, equipment, etc.) based on a shared knowledge space resp. collaborative working environment of the OEM. The suppliers are already in the position to produce and deliver the individual car within two days. This allows a comparison to the "individual" design of an entire arrangement of a room with curtains, coverings, carpets etc. This sort of upgrading would be revolutionary for the home textiles industry as up to now e.g. carpets and comparable fabrics are mass products being either liked or disliked by potential customers. The idea to respond with "one face to the customer" to individual wishes (concerning colour, pattern, quality, price, etc.) applying virtual 3D design to create "aligned" style directions will stimulate the creation of a new market segment within the home textiles industry.

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Semantic Indexing of Documents

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Concurrent use in an image management system

EGYED-ZSIGMOND Előd[1, a], LAJMI Sonia[a] and ISZLAI Zoltán[b]
[a] *LIRIS INSA-Lyon Bât BLAISE PASCAL 69621 Villeurbanne Cedex, France*
[b] *Sapientia EMTE P-ța Trandafirilor 61 540053 Târgu Mureş, Romania*

Abstract. Manual image annotation and keyword based image search is a difficult and hardly formalizable problem. Image processing tools extract and assign keywords to the obtained images, but a manual annotation is almost always essential. In this paper we present a model and a system which addresses this issue. It is an online image annotation and management system, which traces the actions of the users and uses the capitalized experience to help them according to the case based reasoning paradigm. The system provides basic online image gallery features: uploading single or zipped images, describing images with keywords, importing xml based image descriptors, managing galleries … In addition the system helps image annotation tracing the actions of the user in order to propose additional keywords and images as well in the description as in the search phase. This help is provided by the capitalization and the reuse of user's experience based on the case based reasoning paradigm. After a short introduction, we describe our use trace model, the assistance strategies and present the developed prototype.

Keywords: CBR, use trace, trace visualization, assistance, image annotation, case similarity, task model, use model, observation model

Introduction

One of the most persisting problems with large scale collective image management is the description and search of the images. Images, like sounds, videos and other multimedia documents are beyond the semantical gap, which means that their description by words in a given language by a human user goes through an interpretation process. This task is highly subjective and thus very difficult to formalize.

It is important that image management applications provide techniques and user interfaces that can adapt, to be able to fit the needs of a particular task for a particular user. Indeed, for a task such as image description or image search query building it is useful to know how other human users proceeded. Even if formally there is no direct link between past and actual keyword usage, knowing how others annotated, and searched can give precious hints to describe an image or to refine a query. As

[1] LIRIS INSA-Lyon Bât BLAISE PASCAL 69621 Villeurbanne Cedex, France
E-mail: elod.egyed-zsigmond@insa-lyon.fr

computers “do not forget”, it is interesting to keep a suitably modelled trace of use sessions, in order to be able to reuse them to help the realization of new tasks.

Tracing the description and search of images enables to captures implicit knowledge of the individual users in order to reuse it and share it with others.

In this paper, we present a use trace model, which allows the collection and reuse of user experience. This model enables assistance in non trivial, creativity requiring situations. Our model uses the Case Based Reasoning [1] (CBR) paradigm in order to reuse experience. We will detail the case models, comparison and adaptation methods in sections 5 and 6.

In order to do this we trace the actions of the identified user, save the keywords used to describe and to search, together with the search results and the navigation traces. This allows us to suggest keywords to complete the description or to refine the query based on experiences.

In section 2 we present some existing image management tools in order to spot the originality of our work. We make a review of different modeling techniques from the task model in order to position our own design. In this section we describe shortly the case based reasoning paradigm as well and present our approach in calculating

the similarity between the current trace and the saved traces. In the following sections, we first present our use trace model and we explain how we capitalize and reuse experience and present a concrete example of the system.

1. Related work

Nowadays most of the big web companies, such as Yahoo [2], Lycos and others provide personal online photo albums beside the specialized web sites: Flickr[3], Pbase[4], GettyImages[5], Fotovilag[6]. These systems enable the basic operations on the uploaded pictures (description, protected publication, classification into galleries, for some of them keyword based description). The systems can search pictures based on these keywords. Most of them provide an automatic classification by date, some use EXIF[7] data to refine classification. Few enable keyword assignment, but yet again, if it goes to handle several thousands of images the keywords become difficult to find. Desktop applications such as Picasa, Adobe Photoshop Album, and ACDSee are all general-purpose image management tools. They offer better image description possibilities and excellent graphical interfaces to assign keywords to images exploiting the speed and graphical richness of a desktop environment. In the present state of art desktop applications provide better and richer user interfaces than web-based applications, but with the ever-spreading use of technologies such as Ajax, things are changing. Yet either in desktop applications or in web based ones the image management graphical metaphor is still in a maturing phase.

Keyword management is a non-solved problem. Indeed a lot of studies handle their manipulation and leave their structuring as an open issue. From plain, unstructured representations to complex graph based ontologies through tree or hierarchical structures different methods exist. We claim [8] that the creation of a common complex

structure is rather uncertain, so we choose not to organize the keywords used to annotate the images.

Applying artificial intelligence methods to image management systems is quite recent. Collaboration in image archives such as the COLLATE[9], the DEJAVU[10] or the Porphyry[11] systems handle cases when the images are taken from a specialized (medicine, archaeology) field. In general-purpose image management applications collaboration is reduced to comments on other users images. An interesting approach is the one exposed in [3, 12-14] called folksonomy [13] or infoCloud [15] which proposes a bottom-up, socially supported common vocabulary emergence.

The problem with the large-scale use of image management systems is the free choice of keywords.

This means that it is quite difficult to query the images in an efficient way without knowing the exact words used for their description. As the number of pictures, users, and keywords is huge and in addition, the keywords are usually assigned in a very subjective way, the problem of guiding the users in their image annotation and query building tasks is crucial. An intuitive way to address this problem is to propose the reuse of capitalized experience following the case based reasoning paradigm.

2. Modeling user tasks

Our approach is based on tracing the actions of the user. In order to build our use trace model we have studied the existing ones and present them in what follows.

Task and dialogue models emerged from the need to complement domain and application models in order to convey the information required to describe the user's tasks (task model) and to describe the human computer conversation (dialogue model). Task models are fundamental models for user-centered development because they allow designers to construct user-interfaces that reflect the real-world requirements of the end-users. The task model must be decomposed until we reach the basic tasks in order to design the concrete user-interface. When we reached such a level of description, the task model will reflect the human-computer interaction, thus to the task model. This process, commonly known as the transition from task to dialogue [17], is fundamental for adequate user-interface design. It is also important to note that user interfaces and task models are interdependent.

User-interface development approaches that rely on task modelling are commonly known as task-oriented approaches. Task-oriented approaches have received contributions from computer science and cognitive psychology. In the cognitive psychology field, the focus is on the identification and characterization of human behaviour (an activity known as task analysis). Conversely, in the computer science field the focus is shifted towards finding notations suitable to represent tasks and their relationships to support interactive system development [18].

According to Paternò, task-oriented approaches can be classified in three different dimensions as follows [18].

• The type of formalism used to represent the model – which varies from formal grammars to task-action grammars, production systems, knowledge models, transition networks and Petri nets;

• The type of information that they contain – which can be oriented only to identify the activities and logical decomposition or also include indications of temporal relationships, artefacts manipulated and other properties;

• The type of support they provide – which can include evaluation, user-interface design, usability evaluation, and so on;

Many notations were proposed to represent task and dialogue models with the difference in the following aspects: the level of formality, the type of syntax and the richness of operations that they offer to designers involving the capability to concurrent sequential or express operators [18].

Task notations were proposed in the context of the model-based development environments they supported. The most popular examples of diagrammatic task notation were state-transition diagrams (STDs), state charts and Petri nets. State transition diagrams offer an easy display and manipulability of the representation based on a small number of constructs, but with the disadvantages : because state transitions are based on a single event with a single state model, they can lead to an exponential growth in states and transitions in asynchronous dialogues, consequently resulting in large and complex diagrams [19]. A state chart is an extension of the STD which is based on states developed to describe the behaviours of complex reactive systems. State charts add a number of concepts to STDs (hierarchy, orthogonally and broadcast events). The STDs provide increased significant power at the cost of greater complexity.

Even though state charts are an improvement over STDs, the need to explicitly show transitions continued to pose problems for task modelling in particular for modern models and interactive applications [19]. Petri-nets also define possible sequences of events, but require transitions to be explicitly shown, by retracting and cluttering the diagrams.

The problems with the previous notations and the limitations of model-based development lead to their failure in reaching industrial applications [20]. Puerta used interface models to organize and visualize interface design knowledge [21]. We summarized below the main characteristics of these notations:

• LeanCuisine+ is a semi-formal graphical notation for describing the behaviour of event-based direct manipulation graphical user-interfaces in which the behaviour of the interface is expressed in terms of constraints and dependencies, which exist between the nodes of a tree [19]. That task action sequences can be represented in the context of the structure of the interface dialogue.

• Diane+ [22] is actually a design method using a diagrammatic task-based notation in which the procedures are refined through tasks, sequenced with precedence's that express chronological chaining. It is partially possible to generate and manage the user interface and contextual help directly through Diane+ as seen in the modelling tool described in the proposition of S. Lu and al. [23];

• ConcurTaskTrees (CTT) [18] is a widely used task notation in the usability-engineering field: notation developed taking into account the previous experience in

model-based approaches and adding new features in order to obtain an easy-to-use and powerful notation. CTT is a graphical notation where tasks are hierarchically structured and combined using a set of temporal operators. The formal semantics of CTT have been defined [18] and a modelling tool supporting the development of CTT models is publicly available (CTT Environment – CTTe [24]).

As we can see it is important to find the right way to model tasks of a given application. Indeed, task models enable to define an appropriate HMI and in the same time they correspond to existing ones. Task models enable the formalisation of user traces.

We developed in parallel our user interface and task model, based on a state chart. In addition to this trace chart we define an *Observation* and a *Use* model [27] of the application in order to trace it's use. In the next section we present this use trace model.

3. The use trace model

We consider that in a computer application a *user* manipulates *objects* through *procedures*.

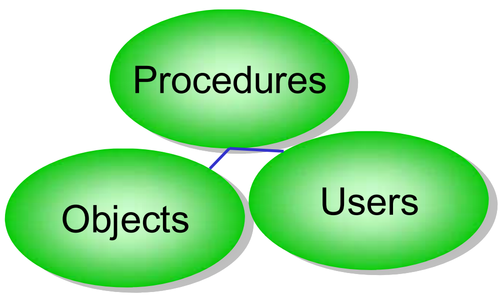

Figure 1: The different use trace categories

The trace model is based on a graph containing *user*, *procedure* and *object* type nodes. The use of the system is traced according to the Club model [27]. In order to create an experience based user assistance we have to go through different phases

- formalize objects manipulated and the relations among them in order to create the *use model*
- gather (imagine) the different object manipulation procedures and formalize them in *tasks*
- decide which tasks to trace in order to capitalize user experience: *observation model*
- the *use model* and the *observation model* enables the *trace* construction
- we provide methods to cut the traces in reusable and adaptable *cases*.

In our system we implemented a simple use trace model to formalize the image search task. The final objective is to develop an experimentation framework to test different use trace models and experience capitalization and reuse methods. We have chosen the problem of image management because it involves highly subjective phases which are difficult to formalize and thus proper to be solved by case based reasoning

related methods. It is important to note that our work aims to provide assistance to the user in *what to do* with the system not in *how to do it.*

The use trace model presented in Figure 2 provides a graph based structure which enables the system to trace users in a well defined manner. The upper part of the figure represents the use trace model, while the lower separated area shows a trace left by a user. The use trace model reflects the scenario enabled by the user interface (

Figure 3). It is tightly related to it. In fact the user interface guides the actions a user can perform. We trace the actions carried out through the user interface.

Each step of this trace is connected to an element of the use trace model. Through these connections the use trace model annotates, explains the trace left by the user. The dashed lines represent the connections between the navigation points in the system and the trace left by the user. This way the trace left by the user can be filtered not only by its intrinsic values but also based on its *annotations*. The trace is not linear but interconnected.

We aim to provide help in a general online image annotation and search use case. In order to be able to capitalize the experience of the users, we have defined a use trace model (upper part of the Figure 2), based on the graphical user interface of the application (Figure 3).

The model gives a formal frame to represent, save and compare traces in order to reuse them. Our cases are defined following this use trace model as well. A case is given by a sequence of the trace. The problem part is represented by the first steps, the solution part by the later ones as defined below.

Once a user connects to the system he begins to leave traces, presented in the lower part of the Figure 2. Each trace step derives from an observation model element, is related to a user and is signed by a timestamp. We can also say that the observation model explains the trace and that the elements of the trace are associated to the elements of the observation model. This latter defines in fact a sort of filter through which the system observes the user.

In order to create reusable cases from the traces, we define case construction methods based on the task and observation model. As we address the search assistance problem, we consider that a case begins with the search step and ends with the image enlarging action. In addition we make a case linear by sorting the trace elements in a chronological order (Figure 6).

In our example; the model defines three users, a set of procedures and objects. The objects are: UserID (UID), Gallery ID (GID), Image ID (IID) and Keyword ID (KID). Our image annotation system handles these kinds of artefacts.

The system is an interactive web application where actions are represented by links, it shows the different objects defined above and enables the keyword based annotation of images related to users and organized in galleries.

The Figure 2 represents only the search phase of the application task model. The procedures are centred around the Search procedure After starting search the user can navigate following different links.

The results are presented as links organized in user galleries (Figure 5).

In what follows we focus on this search phase. For a novice user it is in fact extremely difficult to know what are the keywords used to describe images in the system. We suppose that he starts by typing a set of keywords, launches the search and then navigates in the result images and galleries. In addition the system proposes keywords based on the result image annotations, but also based on the capitalized and reused experience. The basic idea is that it is useful to show a beginner the search phases (query, navigation and results) of other, maybe more experienced users. It may give him a satisfactory result, but in any case it gives him useful hints on how refine his query and find more rapidly an image he was looking for.

We consider the search phase as beginning on the search interface by entering keywords and hitting the search button (Figure 5). This first step is then followed eventually by some navigation steps and ends with the enlarging of an image.

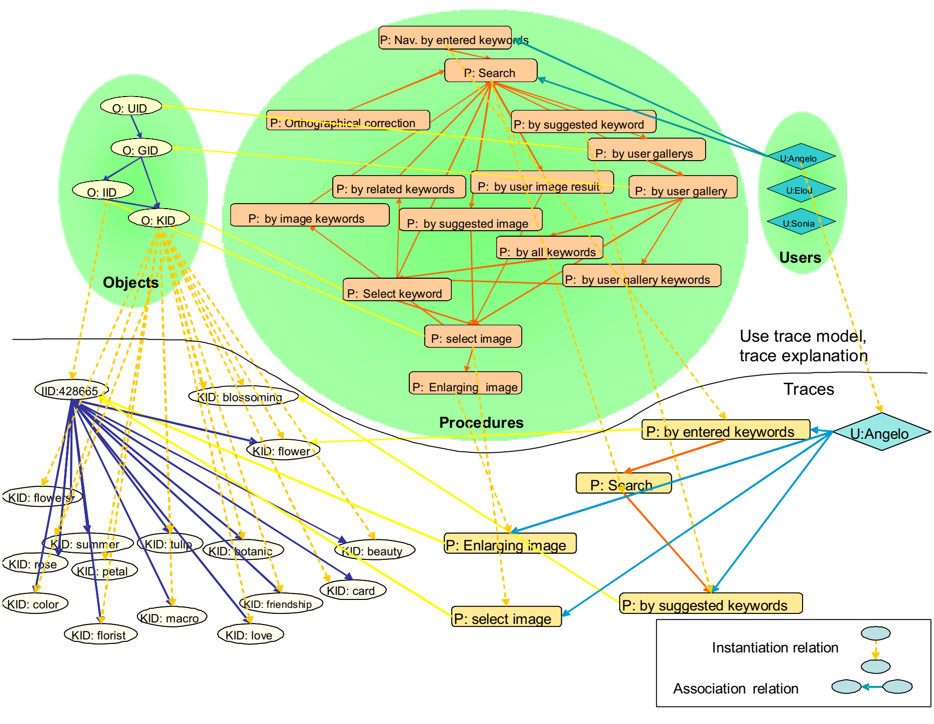

Figure 2: The use and observation model of the prototype application

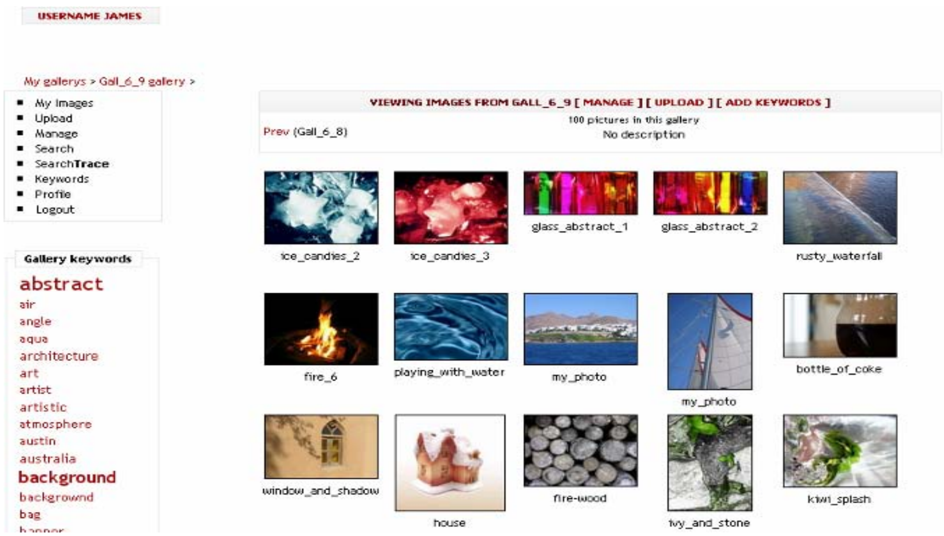

Figure 3: View of a gallery with its keywords and pictures

The different possibilities to navigate through the system are coded in *step types*. These step types together with typed in keywords and other values entered or chosen by the user build the trace. This notation not only simplifies the way we find, process and compare traces, but we are allowing the system to be more expandable because we can simply generate newer step types if the user interface changes and new functionalities are introduced.

4. Tracing users

Case Based Reasoning (CBR) can solve problems by reusing the resolved problems. Building a library of solved problems (cases) would be easiest from a knowledge engineering point of view than building equivalent knowledge bases. CBR finds its roots in research works in psychology [28]; but computer applications have simplified the approach. CBR is less ambitious than knowledge base system KBS because reasoning is analogical with adductive inference: a problem solving episode (a case) is represented by a problem (problem descriptors) and by its solution (solution descriptors). New target problem is solved by adapting the solution of a past similar problem. This hypothesis has to be checked in reality and there is no way to demonstrate that this is the best solution. Checking the proposed solution allows to revise and repair the case before adding it to the cases library.

The more important reason in the big success of CBR consists of being a "learning system" able to add new cases and, theoretically, to improve its domain representation. In order to be able to apply CBR we must first define what a case is in our system, then define case comparison and case adaptation methods. According to [1, 16], a C case is composed from a problem pb(C) and a solution sol(C).

C= (pb(C), sol(C)). The already solved cases are stored in a case base. Solved= (pb(solved), sol(solved)). While capitalizing a new experience, a new case is created

which needs to be solved. This case is: Target= (pb(target), sol(tagret)). In this new case we search the target solution sol (tagret). The analogy rectangle (Figure 4) presents how case based reasoning works.

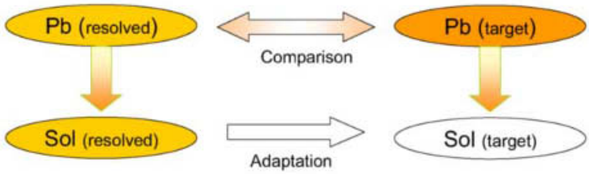

Figure 4: The analogy rectangle

Based on the comparison function we try to find similar cases to a target problem. Once a similar case is found we try to adapt its solution following an adaptation function in order to propose a solution to the target problem.

The trace made by one user must describe the navigation from where the problem started to the point where the problem was solved partially or entirely. In order to do this we have created a graph structure based use trace model. The graph contains navigation points and actions between these points. We define the starting and ending point of each trace in our trace model. The problem is considered finished, when the user reaches the expected navigation point.

Our system follows the users while they search for images. It assists them to describe what they wish to find. Our system suggests to users keywords in order to refine their query and images based on past experiences. As we described above we consider a search process as a reusable case. It is considered started when the user types one or more keywords and hits the search button. The second part ends when the user makes one or more steps of navigation. This search is considered successful when the user enlarges a found picture, and is saved in the knowledge base. In this case the search trace ends with a reference to the found image (it's ID) together with the enlarging action. The navigation begins with the first search results and uses the possibilities defined in the use trace model (i.e.: following galleries, users, images, keywords) to complete. The navigation trace is also part of the problem in our case based model. A trace is also considered finished when the user didn't find the image, and started a new search. In this case there is no solution for the problem in the actual case and we drop it.

The upper part of the interface in Figure 5 presents a trace memorized in the case base. It is created by a user searching for an image. The user starts by introducing keywords in this example it introduces *flower*. When he presses the search button he starts the search procedure by the entered keyword. In the middle the system shows the images described by the keyword *flower,* aside the search box (*Related keywords*) it shows the other keywords used to annotate the result images, ordered by their frequency. In the frame on the right side (*Suggested keys* and *suggested images*) it presents keywords found in similar cases and the result images of these cases. This way even a beginner user can quickly write pertinent queries without much effort, avoiding a long learning and vocabulary discovering process. A search is successful when the user enlarged the image.

In our case the system found 2 keywords (*blossoming* and *red*) coming from 2 different capitalized search traces.

If the user rolls over the *blossoming* keyword in the suggested keywords frame, the system shows the whole case from which this keyword was taken from. In our example the trace contains the *flower* and the *blossoming* keywords as query part of the case, a user navigation step (all images of a user named *andrew* were visualized), a gallery navigation step (the user visualized the contents of the gallery: *Gall_1_6*) and finally ends by the navigation on an image and it's enlarging. This result image is also shown as the first one in the suggested images. The trace shows all the keywords assigned to the result image as well. We can see that the result image is not described by the *blossoming* keyword, but that the user considered it as a good result however.

The problem is finding which of theses traces are more relevant to the current trace; how should we organize these keywords in the interface of suggested keywords? This question is resolved by the theoretical approach which we presented in the following section. We take into account the expertise of the user as well: we look to the length of the navigation steps. The user had searched with blossoming flower found the image in less steps than the user who searched with red flower. In consequence, we consider the keyword *Blossoming* more important than *red* in this search.

If the user clicks on a suggested keyword the search is restarted with the initial query completed by the suggested keyword.

5. Trace comparison

Comparing the traces is a crucial part of the project, because on this feature depends the speed and accuracy of the system. At each search step the system looks for similar traces and proposes the user final results as well as following steps before the actual problem is solved and before the user starts to navigate through the system. The results in our case are images, the intermediary steps are keywords. If the trace comparison doesn't generate a proper solution or only generates partial solutions it can still propose useful hints.

In our prototype we have started with the implementation of a simple query tracing method. A reusable case is considered to be made of the search keywords and a solution image. In this first method we compare only keywords. In this keyword matching process the system saves the keywords entered by a user in a data structure and these saved keywords are used for finding similar search cases. Keyword matching works on a dynamically adjustable statistical approach.

The dynamic change of percentage of similarity is made automatically by the system depending of the success of one trace. At the actual state, the threshold value is fixed by the system administrator.

As described above, we have chosen to show every user their own trace and the traces found similar to theirs.

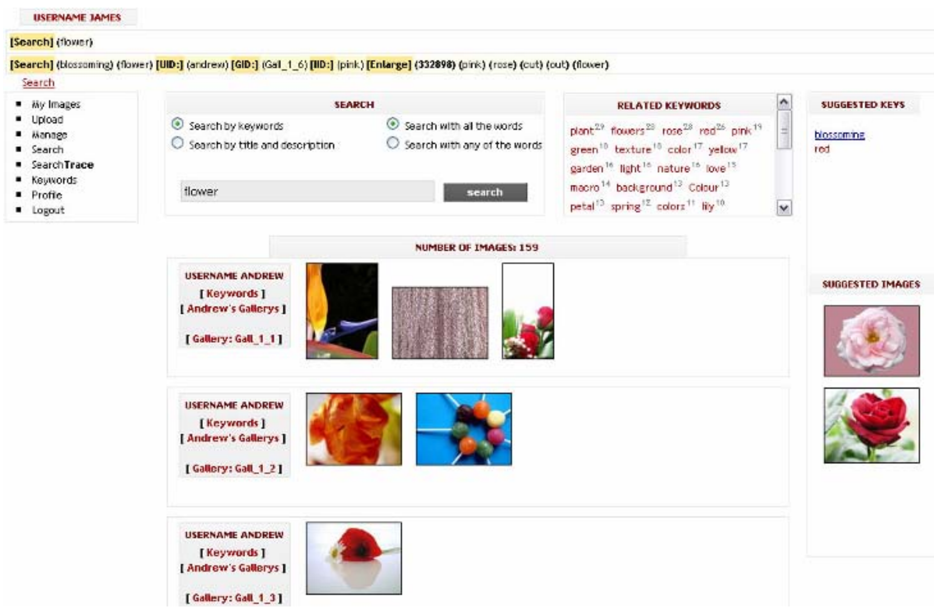

Figure 5: The search interface with results and suggestions

The comparison of navigation traces is the extension of the keyword matching method. In this case the system not only compares entered keywords but also the similarity between the current navigation steps and saved navigations. This way it can propose images and navigation directions which are several steps away from the current state of the user.

We represent the vocabulary used to describe the images as a plain set of keywords to be as general as possible.

When matching traces the system is comparing saved traces from where the navigation began to the current navigation point and tries to see if it equals until the last navigation point. If it finds matches then the system is displaying not only the images found on those traces, but is suggesting the use of keywords from those saved matches.

In a first step we compare only the query part of the traces, that means the keywords. We decided that for this first type of comparison we don't care about the order of the entered keywords, but only about the number of identical ones. We have chosen Tversky's similarity formula [29] on a set of features in order to calculate a similarity value between two queries.

A trace is composed by three parts: request, navigation and result illustrated by Figure 6.

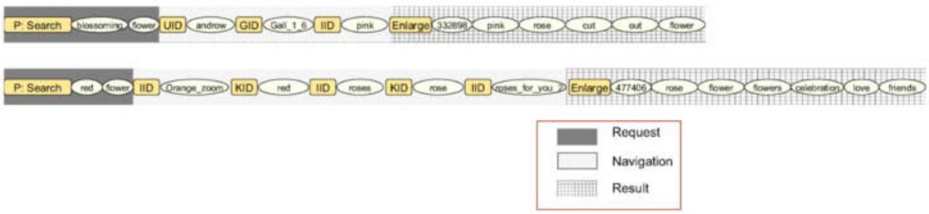

Figure 6: The three parts of the trace

A possible application of this similarity measure is to consider the comparison between requests parts of two traces. The measurement is calculated by dividing the number of common keywords with the number of the distinct keywords. If T_1 and T_2 are 2 traces then this similarity can be noted as:

$$Sim(T_1,T_2)_{Rq} = \frac{N(C(T_1,T_2))}{N(T_d(T_1,T_2))}$$

Where $C(T_1,T_2)$ is the set of common keywords in T_1 and T_2, $T_d(T_1,T_2)$ is the set of all distinct keywords in T_1 and T_2 and $N(E)$ is the number of elements in the set E.

In a second step we could consider the length of the navigation phase. It is a measure that represents in a way the expertise of the user. The shorter the navigation is, the more the user can be considered as expert.

This similarity can be expressed by the formula:

$$Sim(T_1,T_2)_{Nav} = 1 - \frac{\left|L_{T_1} - L_{T_2}\right|}{L_{\max}}$$

Where L_{Ti} is the number of steps in the navigation phase of the trace T_i, L_{max} is the maximal number of steps in all traces.

The global similarity between two traces is then given by the expression:

$$Sim(T_1,T_2) = K_1.Sim(T_1,T_2)_{Rq} + K_2.Sim(T_1,T_2)_{Nav}$$

K_1 and K_2 are coefficients to weight the importance of the two measures.

We are currently working on a third measure between the query parts of the traces taking in count the order of the given keywords.

Each time the user navigates after having begun a search the system looks for the most similar cases in the case base using the similarity measure above and proposes keywords and images according to it.

6. Prototype application

We implemented our capitalization and reuse model in an entirely open source based system. The core is developed in php and Ajax, the web server used is Apache and the database system is MySQL. The images are stored in a file system, keywords, user and trace information in the database. We implemented some user interface ideas taken from existing websites, like keyword resizing following their frequency (

Figure 3). We have also created an original way of suggesting keywords and images (Figure 5) in a non intrusive way, without interfering with the “classical” use of the system. We have added an additional frame on the right side of the interface to show the suggestions.

We are currently working on different trace visualization methods as described in the sections 5 and 6 and presented on Figure 5. We consider that it is important for the user to know how the system capitalizes his experience, how he is followed, so he can adapt his behavior to help the system assist him.

In the system we have also developed a keyword proposition system which aims to help users annotate images. Annotations are different for every user because each user annotates differently each image. We allow every user to annotate with keywords any image, because images have a different meaning for each user in particular.

We display the keywords of the user to help annotating the image, and we highlight the keywords which were already used to annotate the image.

For helping the annotation process we also propose keywords for the user. These keywords can be grouped in three different ways.

The first kind of keyword proposal we aim to provide a classical manner of annotation: keywords are ordered alphabetically and the user can paginate between these keywords. Yet as we have more than 500 keywords in our system actually it is hardly usable.

In the second part we aim to provide related keywords to current keywords which were already used. Also note that this is possible only when the currently selected image was already annotated by the minimum of one keyword. This method consists of finding images in the system which were already annotated by the keywords of the currently selected image, and finding the keywords which are different from the keywords used for annotation. After finding these keywords we sort these keywords by frequency and propose them to the user.

In the third part we use an image similarity measure to find images which are close to the currently selected image. This similarity measure is a very simple one, based on colour distribution in the image.

For each image we calculate an associated image data vector. The image data consists of blocks of information regarding the colour composition of the block. Each image is divided to a number of equal blocks. For each part the average colour channel distribution is calculated and each of these parts is saved in the database. When the system compares images it compares the image data and it searches the lowest difference between the blocks. When comparing images we search for images that are similar to a selected image. After this step we extract the keywords from these images and we sort them by frequency.

In the system the users can browse by keywords. When a user navigates by a keyword the displayed images are those annotated with the selected keyword. Also are displayed the keywords which are in relation with the selected keyword. The relation consists of searching all the images which are annotated with the selected keyword and finding all the keywords which are used to describe these images. After this step all the keywords are sorted by frequency.

7. Conclusion and future work

In this paper we have presented a user tracing online image annotation and management system. This system implements a case based reasoning use trace model and provides a non intrusive way of suggesting keywords and results to help users describe what they wish (dream) to find. This system provides an experimentation framework to implement and test other case base reasoning techniques, use trace models, user interface issues and also as an illustration of the theoretical models developed in our lab.

The system provides an original way of modelling use traces, transforming them into reusable cases. We have provided some case comparison methods using the domain knowledge on general image annotation.

The trace model we implemented enables the capitalization of certain facets of users' culture, knowledge. This knowledge is explicated according to our trace models and can be reused according to the case comparison techniques. The reuse of the capitalized experience leads to a better organisation of knowledge.

Our work continues in three directions:

1. The first one is the implementation of specialized communication layer with automatic and assisted image processing and optical character recognition tools. This will include OAI (Open Archives Initiative) compliant XML based input output modules and ontology input and output layers.
2. The second one is theoretical and aims to refine the use trace model in order to assist in every phase of the use of the system, keeping the model as generic as possible. The fact that the traces are graph shaped gives us many linearization possibilities which means we have several case construction, comparison and adaptation methods. We are also looking for novel needs and try to identify new image management related problems that can be assisted using our model.
3. The third direction of our research is more technical and heads to the implementation of novel graphical user interface techniques and visual metaphors. We have thought about using even more javascript, ajax and SVG technology to be able to annotate image regions and locate precisely extracted words in documents. The novel interface issues concern the trace visualization as well. It is important that the user be aware that he is followed, that he feels in control of what happens and that he can modify the parameters of tracing.

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Multilingual Indexing Based on Ontologies

Catherine Roussey**- Sylvie Calabretto*- Farah Harrathi* - Mohamed Gammoudi+
**LIRIS CNRS UMR 5205 - INSA de Lyon, Bâtiment Blaise Pascal 7, avenue Jean Capelle, F-69621 Villeurbanne Cedex {firstname.lastname}@insa-lyon.fr*

***LIRIS CNRS UMR 5205 - Université Lyon 1, Bâtiment Nautibus 8, boulevard Niels Bohr F-69622 Villeurbanne Cedex {firstname.lastname}@liris.cnrs.fr*

+Unité de recherche en Algorithmique, Programmation et Heuristique ISIG Kairoun - Université de Kairoun (Tunisie) mohamed.gammoudi@fst.rnu.tn

Abstract. This article deals with multilingual document indexing. We propose an indexing method based on several stages. First of all the most important terms of the document are extracted using general characteristics of languages and statistical methods. Thus, term extraction stages can be applied to any document whatever the document language is. Secondly, our indexing method uses a multilingual ontology in order to find the most relevant concept representing the document content. Our method can be applied to a multilingual corpus containing document written in different languages. This indexing procedure is part of a Multilingual Document System untitled SyDoM, which manages XML documents.

Keywords: Information Retrieval, automatic indexing, multilingual corpora, domain ontology, natural language processing, statistical analysis.

1. Introduction

This article presents an extension of the SyDoM project. SyDoM is an information retrieval system based on ontologies [1]. Thanks to this system, user can query with the language of his choice a set of documents written in different languages. SyDoM is composed of three different modules: an indexing module, an ontology management module and a retrieval module. The indexing module of SyDoM enabled a librarian to compose manually document indices. Thus, this manual procedure is not adapted to the treatment of large-scale corpora. Consequently, SyDoM should now integrate automatic indexing method in order to extract document index from text. Various works propose terminology extraction tools. For example, the most used French extractor tools are LEXTER, TERMINO [2] and NOMINO [3].

We proposed a new multilingual indexing method. The goal of this method is to identify automatically the most relevant concepts representing the document content. This method extract the most important terms of the document based on general characteristics of languages and statistical methods. Then these terms are matched to a multilingual ontology in order to find the most relevant concepts representing the document content. Our term extraction method is based on frequency distribution. Several metrics are calculated: among them we can notice mutual information and association degree.

First of all, the theoretical bases of the SyDoM prototype will be presented. Secondly, the proposed automatic indexing method is described. And finally, we conclude by presenting the project perspectives.

2. SyDoM Prototype

SyDoM is a multilingual information retrieval system. Thus, when the user queries a collection of document using the SyDoM prototype, he can retrieve several documents written in various languages. The document language can be different from the query language. SyDoM is based on a semantic thesaurus, which is a new kind of lexical ontology. A semantic thesaurus links a domain conceptualization to several terminologies. Thus terms are dissociated from concepts. More precisely, a concept is an object, which identifies a term meaning, and a term is an object, which identifies a concept label. This separation enables to clarify the link between concepts and terms. For example a polyseme is linked to several concepts and synonyms are linked to the same concept. Indeed the semantic thesaurus enables to categorize several kinds of relations: terminological relations linking terms with concepts like synonymy relation and semantic relation linking two concepts like "kind of" relation.

For more information, semantic thesauri are defined in [1]. Two kinds of knowledge are identified in a semantic thesaurus:

1. Domain knowledge constitutes the domain conceptualization thanks to concept types and relation types. This domain conceptualization is the result of a consensus between the different actors of the domain. Indeed, these relations and concepts types compose a pivot language used by SyDoM. The conceptualization is equivalent to the support of conceptual graph model defined in [4].
2. Lexical knowledge is composed of terms grouped in vocabularies. Terms are defined as linguistic manifestations of concepts in text.

From this semantic thesaurus defining domain knowledge and lexical knowledge, semantic graph are used for indexing documents. A semantic graph is a set of concept nodes connected to each other by relations. Semantic graphs can be compared to Conceptual Graph. The figure 1 presents an example of semantic graph (in the conceptual graph formalism). This graph is used to index a document dealing with "*diesel combustion*".

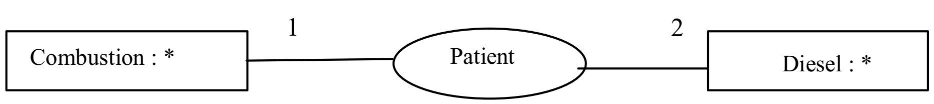

Figure 1: A semantic graph composed of two concepts linked by a relation.

The following section presents our automatic indexing method for multilingual documents. This method is based on Natural Language Processing works (NLP). The multilingual indexing has to break the language barrier in order to compare the user query to the document index. Two automatic indexing methods exist for multilingual documents. The first one uses Latent Semantic Indexing (LSI) method on parallel corpora [5]. This type of corpus is composed of documents and their translations in all

languages. The second one is an endogenous approach. This approach only uses the corpus and does not need any other linguistic resources [6].

3. Concept extraction method for multilingual documents.

Our method is based on:

- statistical methods from NLP works. Our method uses mutual information, association degree, and frequency distribution of terms.
- general properties of natural languages.

Section 3.1 presents the theoretical bases of our approach. Then, section 3.2 describes the concept extraction method.

3.1 Theoretical bases of our method

This section describes our work hypothesis used to determine concept occurrences appearing in text. Probabilistic measures used to extract concept occurrences will be explained.

3.1.1 Contextual Distribution of term in corpus

The contextual distribution of a term inside a corpus is defined as the different context of term use in a corpus [7]. The Figure 2 presents 8 different formal representations of sentences belonging to the same corpus. In these formal representations terms are represented by a Ti symbol.

1) T1 T2 ; 2) T3 T4 T1 ; 3) T5 T2 T3 ; 4) T3 T2 T5 ; 5) T3 T4 T5 ; 6) T1 T4 ; 7) T5 T4 T3 8) T3 T2 T1

Figure 2. 8 sentences of a corpus.

Considering the term T2, its contextual distribution in the precedent corpus is : (T1), (T5-T3), (T3-T5), (T3-T1). And the contextual distribution of the term T4 is : (T3-T1), (T3-T5), (T1), (T5-T3).

One can notice that the distribution of the term T2 is identical to the distribution of the term T4. Thus, we assume that these 2 terms belong to the same class that is to say they are two distinct occurrences of the same concept. This assumption introduces our first hypothesis:

> **Hypothesis 1**: if 2 terms have similar contextual distributions, then they are 2 occurrences of the same concept.

3.1.2 Mutual Information

A term can be composed of several words. Then if a sequence of words appears several times in a corpus of a specialized domain, this words sequence has strong probability to represent a term of the domain [4]. The mutual information, noticed IM, evaluates the association power of 2 words (M1,M2). Indeed, IM compare the probability to find the 2 words together in the corpus to the probability to find them separately in the corpus. The definition of the IM is as followed:

Eq(1). IM(M1, M2)=log2(P(M1,M2)/(P(M1)P(M2)))

P(M1) is the probability to find the word M1 in the corpus; P(M2) is the probability to find the word M2 in the corpus; P(M1,M2) is the probability to find the 2 words M1 and M2 together in the corpus.

If IM(M1,M2) > 0, then the words M1 and M2 appear together in the corpus.

If IM(M1,M2) ≈ 0, then M1 and M2 have no link.

If IM(M1,M2) < 0, then M1 and M2 have complementary distributions.

The table 1 shows an example of word frequencies in order to apply the calculation of IM.

Frequency of the word « graphe »	9313
Frequency of the word « conceptuel »	8205
Frequency of the word « conceptuel » located at the position (p+1), such as the word « graphe » is located at the position (p)	7522

Table 1. Example of word frequencies.

Thus, « graphe conceptuel » is considered as a compound term of the domain.

Hypothesis 2 : If 2 words, T1 and T2, appear together in the corpus several times domain untitled a compound term.

3.1.3 Association Degree

Association Degree estimate the probability to observe a term T2 such as the term T1 has already being observe in the textual unit [9], that is to say it estimates the conditional probability P(T2/T1). This function called Ia is neither symmetric nor anti symmetric. It is defined as follow:

Eq (2). Ia(T1, T2)=P(T1, T2)/P(T1)

P(T1) is the probability to observe T1 without observing T2 in the rest of the textual unit. P(T1, T2) is the probability to observe T1 followed by T2 in the same textual unit.

If Ia(T1,T2) > 0 strongly positive then T1 and T2 appear often together in the specified order. Thus, T1 and T2 can be linked.

Hypothesis 3: if 2 Terms (T1 and T2) appear together in the same order in several textual units of the same corpus, then we assume that they are linked.

3.1.4 Natural language properties

Our work uses 4 properties of natural language:

Principle of Least Effort

The first property is based on the Zipf's Principle of Least Effort. Apply to language, this principle states that a speaker will reduce the length of frequent words. Thus empty words, which appear frequently in a text, should have the shortest length.

Saussure theory

The second property is a consequence of the Saussure theory. This theory implies that “languages are made of difference”. Thus, locale differences can be calculated to identify empty words from non-empty words. The differences between word length or word frequency can be studied like in the Zipf’s Principle. [10]

Words sequence in text

Texts are made of sequences of empty words and non-empty words. These words do not follow each other randomly in text. Words sequences can match 2 patterns: NEN or NEEN (N state for non empty word and E state for Empty words [6].

Principle of Term Uniqueness

Textual unit is a sequence of word without repetitions. Words can be terms. The next hypothesis is based on this principle.

> **Hypothesis 4**: in a textual unit, two occurrences of the same term cannot be found.

3.2 Concept extraction from texts

In this step, we try to extract concepts from multilingual corpora. The manual extraction of these concepts is a very “heavy” task. Thus, we have to find an automatic or semi automatic method that would ease the indexing process even if the result would not be as relevant as a manual indexing method.

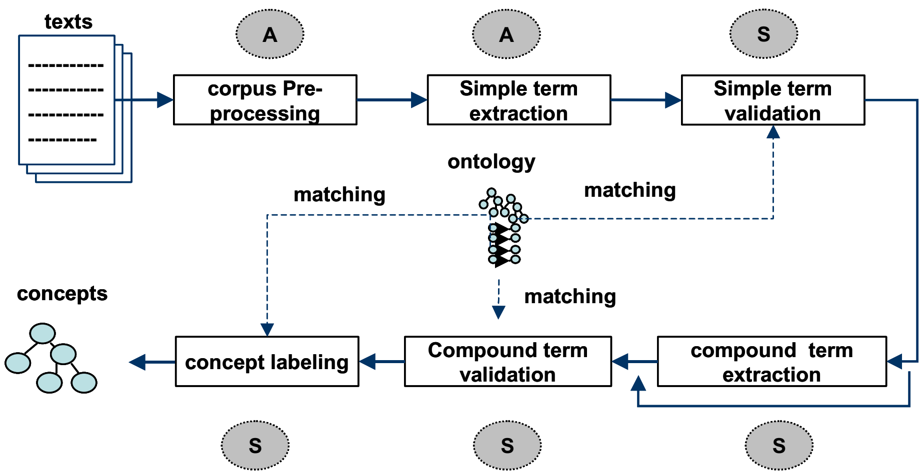

Figure 3: The steps of concept extraction from text

The figure 3 summarizes the steps for the concepts extraction; these steps are semi-automatic (S) or automatic (A). The validation steps are carried out by linguist (or by several linguists because of the multilingual aspect of the corpus).

3.2.1 Pre-processing of the corpus

The corpus pre-processing is a preliminary step in the indexing process. This step determines the lexical data (list of words, their frequencies or number of occurrences and their position in the corpus) that will be exploited in the later steps. In this step, the text is cut in words by using the separation characters and punctuation characters. The result of corpus processing step is the list of words. This list contains the words, their frequency, their size and their position in the corpus.

3.2.2 Extraction of simple terms

The extraction process of simple terms is composed of two distinct steps. The first step categorizes words in empty words and non empty words in order to determine the candidate term. The second step validate the candidate terms. The validation is made, first by a matching operation on the ontology and then by a linguist. All the candidate terms that are validated become terms.

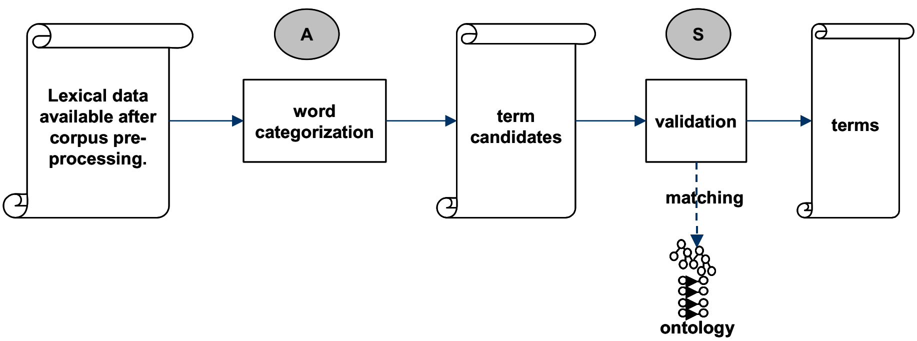

Figure 4: Steps of terms extraction

Words categorization: the word categorization determine for each word its category: empty or non empty. We used the endogenous method of J. Vergne [6].

Validation and generation of simple candidate terms: this step is made on two times. First, we proceed to a matching operation. This operation consists in searching in the ontology the set of candidate term. The candidates, which exist in the ontology, are automatically validated and become terms. Next, one or several linguists have to examine the non-validated terms by the matching operation in order to validate them if necessary.

This semi automatic validation step is necessary because the categorization process can extract words that do not correspond to a term. Indeed, a term is not defined with respect to its form but with respect to its function in the domain.

3.2.3 Extraction of compound terms

The creation of a new concept in the domain does not imply the creation of a new and independent term (fast explosion of the lexicon) [7]. Indeed the term use to represent this new concept is created by combining already existing terms. Our term extraction process is based on this principle. Compound terms are extracted from the list of simple terms.

The extraction process of compound terms that we use is an iterative and incremental process. It allows discovering new terms (compound terms) from existing terms. The process will extract new terms from an initial list of known term by using the mutual information presented before. The initial list corresponds first to a list of simple terms validated in the following step; it corresponds after to intermediate results. This process uses initial terms for discovering new terms. These new terms are then used for extracting new terms and so on (iterative process). The extracted terms are added to the initial list, after each iteration (incremental process). The stop condition is satisfied when terms are not discovered any more.

The extraction of compound terms ends by a validation step identical to the validation step of simple terms.

3.2.4 Concept labeling

In this step, we associate to each term its different contexts using the hypothesis that "if two terms have the same contexts then they are semantically closed". Thus, a term will be represented by a matrix of 2XN elements (N is the term frequency in the corpus). This matrix contains the N terms of its left context and the N terms of its right context. For example, when we have the phrases : "The inventory of products in the warehouse ", "The inventory of products in the store" et "The inventory of products in the dump", we can supposed that the terms « warehouse », « store » and « dump » belong to the same concept. The terms are first gathered in different classes in function of their contextual distribution in the corpus. Then, an appropriated concept name has to be found for each group of terms (concept labeling). In this labeling phase, the classes of terms are matched to the ontology. In this step, the matching searches for a concept in the ontology, that contains at least one term of the class of terms. If this concept exists, the name of the concept is affected to the class of terms. The classes of terms not labeled by the matching method are manually named. The Figure 5 shows an example of nomination of class of term.

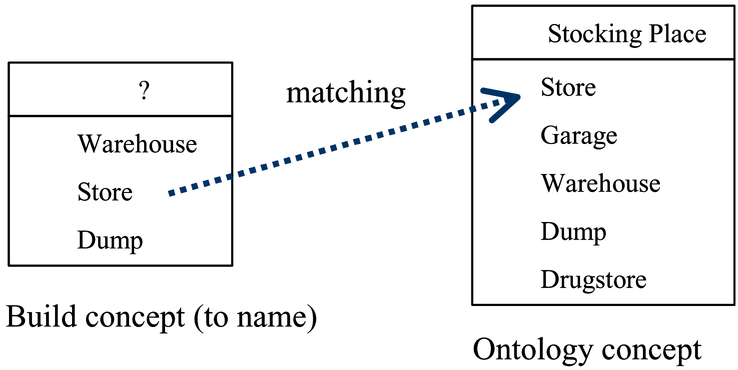

Figure 5: Example of concept labeling

In this example, a class of terms found in the corpus is composed of "warehouse", "store", "dump". There exists in the ontology a concept "Stocking place" containing the term warehouse. Therefore, the class of terms is labelled by the concept "Stocking place".

4. Conclusion and perspectives

The combination of linguistic and statistic approaches have been already used in other works. For example, the tools SYNTEX or XTRACT [11] or [12] combine these two types of approaches. In all these approaches, it is necessary to know the unique language used. Our approach, on the contrary, is valid on all the languages contained in the ontology, because it uses neither syntactic analysis, nor stop list. This approach is able to locate simple and compound terms, to construct concepts by gathering terms in different classes. The calculi are independent of the languages and are not sensible to the adding of a new language. We have validated our approach by comparing the results with respect to a monolingual extraction tool: TerminologyExtractor (http://www.chamblon.com). The two tools give similar results. We aim, in next studies, to define a methodology of extraction of relations between concepts, for generating semantic graphs indexing documents. So, we can integrate our approach in the indexing system of the SyDoM tool [1].

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Using External Knowledge to Solve Multi-Dimensional Queries

Saïd RADHOUANI and Gilles FALQUET
Centre Universitaire d'Informatique. Université de Genève
24, rue Général-Dufour, CH-1211 Genève 4, Switzerland
{Said.Radhouani, Gilles.Falquet}@cui.unige.ch

Abstract. To improve the precision of an information retrieval system in a specific domain we propose a new indexing scheme based on external knowledge resources such as thesauri or ontologies. We introduce the notion of domain dimension, which is a substructure of a knowledge resource, to formally represent the different aspects of a domain that appear in a document. Then, we identify dimensions in documents and queries using a conceptual indexing. The result of this indexing is a representation of each document along its semantic dimensions. We also propose a query processing based on multi-dimensional indexing. It is comprised of a dimensional filtering followed by a dimensional ranking.
Experimental results on medical imaging documents (ImageCLEFmed-2005 collection) show that the dimensional filtering, using three dimensions, can improves the mean average precision by about 25%.

Keywords. Conceptual indexing, multi-dimensional analysis, external knowledge, UMLS

Introduction

In specific domains such as medicine, the information retrieval task differs from general case the vocabulary is precise and less ambiguous than in the general language. When a user seeks information, he or she can express his information need using the specific technical vocabulary containing terms whose meaning is precise. To obtain precise answer during the IR process, documents and queries should be interpreted by minimizing the risk of error. In this paper, we investigate which effects can be achieved for precision of information retrieval by integrating external knowledge although a large meta-thesaurus to process medical queries.

In order to evaluate our approach, we carry out an empirical evaluation on the ImageCLEFmed-2005 collection. This collection contains images annotated in three languages. The queries are composed of image-examples and a textual description explaining the goal of research. The example shown in Figure is one of the 25 queries of the CLEF Medical Image Retrieval Task [4]. In this query, it is clear for a human reader that we are looking for images that contain two elements: one part of the **anatomy**, namely *femur*, and one **pathology**, namely *fracture*. These two elements are semantically related. The fracture is a pathology of a bone such as the femur. These two elements should be described in images whose **modality** is *x-ray*. Thus, x-ray images that contain "*a frac-*

ture of a cranium" or "*a femur without fracture*" are supposed not relevant to this query. Also, we suppose that images containing "*a fracture of a femur*" and whose *modality* is not *x-ray* are not relevant to this query.

Figure 1. A query example extracted from the ImageCLEFmed-2005 base

Observing the set of queries in ImageCLEFmed-2005 collection, we have noticed a regularity of this phenomenon. Indeed, almost all queries contain these three elements (anatomy, pathology, and modality). Hence we call them the **dimensions** and we define them as follow: "*a dimension of a domain corresponds to a point of view according to which one can see this domain. It is comprised of a part of the domain vocabulary and has an internal semantic consistency*".

We suppose that an author uses dimensions of his domain of interest to represent the theme of his document[1]. We also suppose that a user uses dimensions of his domain interest to describe his information need. Hence, we make the assumption that a relevant document to one query with dimensions is the one that fulfils correctly to these dimensions.

In order to solve such multi-dimensional queries, we propose to take into account this concept of dimensions during the information retrieval (IR) process. Existing IR approaches are based on statistical methods that use distributions of key-words to compute the similarity between the query and the documents of the collection. These approaches can not solve multi-dimensional queries because they do not take into account their dimensions. Indeed, these approaches consider documents and queries as bags of words.

To solve multi-dimensional queries, we propose to represent the semantic documents (queries) content using their dimensions. For this reason, the dimensions should initially be defined and then, identified in the documents and queries. The dimensions depend on the organization of the studied domain. We suppose that external knowledge, described through an external resource (linguistic: thesaurus or semantic: ontology), can define the domain dimensions. The external resources contain concepts and semantic relations that constitute the dimensions. Hence, the identification of the dimensions from documents (queries) requires extracting concepts that describe them in documents (queries). This can be done through a conceptual indexing using the selected external resource. Thus, these are the main problems that we face:

- Choosing the external resource and defining the dimensions;
- Extracting the concepts from text to be indexed;
- Identifying the dimensions from documents and queries;
- Taking into account the dimensions during the indexing and querying processes.

[1] For instance, a doctor uses the dimensions anatomy, pathology, and modality to write a report corresponding to a patient.

In the rest of this paper, we present some related works (cf. section 1). We define the external resource and the dimensions in section 2. We introduce the document module and the query module in sections 3 and 4 respectively. For the evaluation (cf. section 5), we investigate the ImageCLEFmed-2005 collection. Finally, we conclude and present our future works (cf. section 6).

1. Related works: external knowledge-based information retrieval

The idea of using external knowledge for IR has been largely explored but with relatively little success. The principal proposals relate to the query expansion. For example, Voorhees [19] who extends queries by using semantic lexical relations (WordNet synsets). The major problem which is faced is related to the ambiguity (i.e. chose the synsets that contain the correct meaning of the terms). Experimental evaluations did not give good results even with manual disambiguation. Qiu and Frei [18] obtain better result by choosing the concepts which are semantically related to the entire query rather than to the individual terms of the query. In the same way, Baziz [6] studied the use of different type of semantic relations for the query expansion. He proposed a technique that makes it possible to choose "the best" concept to add during the expansion process. Based on this technique, he proposed two expansion methods: (1) the "moderated expansion" which consists to add, for each term of the query, only one concept by type of relation, (2) the "careful expansion" that consists to add, for each query, only one concept by type of relation. The experiments show that the careful expansion gives the best results. This conclusion confirms that drawn by Qiu and Frei [18].

The external resources were also used for terms disambiguation. For example, Gonzalo et al. [13] studied the impact of the terms ambiguity based on manual disambiguation and the introduction, voluntarily, of errors of disambiguation. They show as well as the system functions better with conceptual indexing with less than 30% of disambiguation errors. Baziz et al. [5] propose a disambiguation technique and show that an indexing based on a combination of concepts and words, improves the quality, contrary to an indexing based only on concepts. The authors think that the failure is due to the weak covering by the used resource (WordNet) on the vocabulary of the corpus.

In the medical domain, several works used the UMLS meta-thesaurus for the indexing of medical documents [14]. The benefit of such indexing is not very clear, and it is sometimes, while combining once again, the conceptual indexing with the word-based indexing that a small improvement can be obtained [2,3].

Concerning the concept of dimensions, Hyvönen et al. [15] have proposed an interface for navigation in a base of images. The navigation is based on manually built ontologies. Each ontology describes one of the dimensions present in the base (ex. person, event, etc). The interface thus makes it possible to carry out an access to the base according to different dimensions. Each dimension corresponds to a point of view according to which one can explore the base. In the same way, Aussenac-Gilles and Mothe [4] proposed an ontology-based interface for navigation in a base of textual documents. The authors assume that ontology is complex and makes the interface not easily usable. They thus propose to divide ontology into different hierarchies; each one corresponds to one of the dimensions present in the base (example of the astronomy domain: astronomical objects, measuring instruments, observatories, etc). Hence, the multi-dimensional access to the base is made through the defined hierarchies.

From the existing works, we can note that the use of external resources is a good solution to have a precise representation of documents and queries. Indeed, the conceptual indexing combined with a word-based indexing allows the improvement of the answers precision. Good results have also been obtained with the query expansion, which represents a means for enhancing the recall. However, the conceptual indexing and the query expansion are not sufficient to solve multi-dimensional queries. Indeed, in these two cases, documents (queries) are considered as bags of concepts and dimensions are thus ignored. We think, that in addition to the conceptual indexing, a transverse organization on the concepts is necessary to define dimensions and to organize research according to these dimensions. Possible solutions of dimensions definition have been proposed in [15,4]. However, in these works, there is no solution to solve multi-dimensional queries. In the following sections, we present the use of an external resource for solving multi-dimensional queries.

2. External knowledge-based dimensions definition

To be able to set up a conceptual indexing and handle dimensions, we need external resources that must at least have a lexical structure (association between terms to concepts), and a semantic structure (relationships between concepts, e.g. an *is-a* hierarchy). Thesaurus or ontology, for example, can have these characteristics.

The formal model of an external resource S is a 5-tuple $[C, \leq c, R, T, F]$ where:

- C is a set of concepts $\{c_i, \ldots, c_s\}$;
- $\leq c$ is a partial order on C, called the concept hierarchy;
- R is a set of binary relations $\{R_1, \ldots, R_k\}$ on C, where each R_i corresponds to a semantic relation type (typical types are *part-of, instance-of*, *consequence*, etc.);
- T is the lexicon of the external resource. It consists of a set of terms $\{t_i, \ldots, t_r\}$;
- $F \subseteq T \times 2^C$ is a function that associates each term to the set of concepts it designates (if t_i is polysemous $F(t_i)$ has more that one element).

Then, we propose to define the *dimensions* relatively to one or several external resources. A dimension Dim_i is a substructure of the external resource S. For instance, the pathology dimension of the medical domain is a substructure of the UMLS metathesaurus. In some cases a dimension can be the whole external resource. Finally, we define a *domain* as a set of dimensions.

It should be noted that it is illusory to think that a single hierarchical classification can satisfies all the experts of a domain, because any classification presents the reality in an always-debatable point of view. This is important because the use of a classification for indexing means imposing a point of view on any user of an IRS. This is why we use an external knowledge model that can be made of several, non-related, knowledge resources. Thus the dimensions need not originate from the same knowledge resource.

In a practical perspective, our experiments have shown that it is relatively easy to manually extract a dimension from a vast knowledge resource such as UMLS.

3. Document module

We propose to take into account the dimensions to represent the semantic content of the document. Our idea is that a theme developed in a document D is described through a set

of dimensions of the domain to which D belongs. Each dimension is represented in the document by a set of concepts, denoted by terms, and contributes to expose the theme present in this document. Thus, we analyze documents at two levels:

- *Dimensions*: to identify the dimensions that describe the theme present in the document;
- *Concepts*: to identify the concepts that describe each dimension.

Hence, the questions that we face are: How to identify concepts and dimensions from the document? How to use concepts and dimensions to represent the semantic content of the document?

In the following we assume that each document of the considered corpus belongs to one domain and hence contains concepts from at least one dimension of its domain.

3.1. Conceptual indexing

Let us consider a document $D = \{t_1, \ldots, t_n\}$, where the t_i's are the terms occurring in D. The conceptual indexing consists in selecting, relatively to the external resources, a set of concepts that will represent this document. This step substitutes to each term, one or more concept identifiers. The terms that are not associated to any concept in the external knowledge resource are ignored. The resulting conceptual document D_c is a set of concepts $D_c = \{c_1, \ldots, c_m\}$, where each c_i belongs to $F_k(t_i)$ for some term t_i and some external resource S_k. At this stage, there is no attempt at disambiguating terms. A term will be replaced by two or more concepts if it belongs to more than one resource or if it is ambiguous.

3.2. Identification of the document dimensions

The identification of document dimensions consists in distributing each concept c_j of D_c in one sub document d_i depending on its belonging to the dimension Dim_i. Finally, the document is represented as follow: $D_{dim} = \{d_1, \ldots, d_m\}$, where m is the number of dimensions occurring in D_c, $d_i = \{c^i_1, \ldots, c^i_{k(i)}\}$ is the sub document corresponding to the dimensions Dim_i, $c^i_{k(i)}$ is a concept belonging to the dimension Dim_i, and $k(i)$ is the number of concepts in the document dimension d_i. The set of document dimensions pertaining to the dimension Dim_i is denoted by Dim^d_i.

3.3. Multi-dimensional indexing

We suppose that a document dimension d_i can be an answer unit to a query that asks only the dimension Dim_i. Thus, we consider d_i as an independent document. In order to query each document dimension, we index it using the Vector Space Model (VSM) [20]. The document dimension d_i is hence represented by a vector of concepts $\overrightarrow{d_i} = (w_{c1}, \ldots, w_{ck})$, where each w_{cj} is the weight of the concept c_j in d_i. It corresponds to the importance of the concept c_j in the document dimension d_i. The importance of a concept depends on its frequency in the document dimension, and on its relations with the other concepts of the same document dimension. We suppose that the more frequent the concept in the document dimension, the more important it is. We also suppose that the more semantic relations the concept has with other concepts of the doc-

ument dimension, the more importance it has. Thus, w_{cj} is calculated by taking into account the normalized frequency $F(c_j)$ in the document dimension d_i (see formula 1), and the cumulative semantic similarity of the concept with the other concepts in the same document dimension.

$$F(c_j) = \frac{\text{Freq}(c_j)}{max_{x=1..n}(\text{Freq}(c_x))} \tag{1}$$

- $\text{Freq}(c_j)$: the absolute frequency of c_j in a document dimension;
- n: the number of all different concepts occurring in Dim_i^d;
- $max_{x=1..n}(.)$: the maximum value of a concept frequency in a document dimension.

The cumulative semantic similarity is based on the semantic similarity between two concepts. There are many ways to define semantic similarities in ontologies or thesauri. In our context, we use the similarity measure defined by [21] which has been tested in [12] and gave good results. It is based on the hierarchical position of the least common subsumer of two concepts.

The cumulative semantic similarity, noted $\widehat{\text{sim}}(c_j)$, is the sum of all the semantic similarities calculated between c_j and all the other concepts included in the studied document dimension d_i. The measure is shown in formula 2, where $\text{sim}(c_j, c_p)$ is the semantic similarity calculated between c_j and c_p.

$$\widehat{\text{sim}}(c_j) = \sum_{c_p \in d_i \setminus \{c_j\}} \text{sim}(c_j, c_p) \tag{2}$$

Finally, the weight w_{cj} is a linear combination of the weighted normalised frequency and the cumulative semantic similarity of c_j (cf. formula 3).

$$w_{cj} = \frac{aF(c_j) + b\widehat{\text{sim}}(c_j)}{a + b} \tag{3}$$

Where a and b are two constants that indicate the relative importance of the frequency and the semantic cumulative similarity.

4. Query module

We propose to take into account the dimensions to interpret the user information need from his query. Our idea is that each user describes his information need through a set of dimensions of his interest domain. Each dimension is represented by a set of concepts and contributes to detail the idea expressed by the user. Thus, these are the questions that we face: How to identify concepts and dimensions from the query? How to use concepts and dimensions to represent the semantic content of the query?

Let us represent a query $Q = \{t_1, \ldots, t_n\}$, where each t_j is a term occurring in Q. For the identification of concepts and dimensions from the query, we use the principle presented in the document module (Section 3). After the conceptual indexing and the dimension identification, a query is represented as follows: $Q_{dim} = \{q_1, \ldots, q_m\}$, where each $q_i = \{c_1^i, \ldots, c_{k(i)}^i\}$ is the sub query corresponding to the dimension Dim_i and m

is the number of dimensions occurring in Q_c. The elements of q_i are the concepts of Q_c that belong to Dim_i. Each q_i is thus a conceptual representation of an aspect of the query.

Our main hypothesis is that a document is relevant for a query if it is relevant for each dimension of this query. Thus, to solve multi-dimensional query, we propose to use its dimensions to filter the documents during the querying process. The relevance of a document D with respect to a query Q is hence given by a combination of two techniques:

- *Filtering* selects documents that contain the query dimensions;
- *Ranking* ranks the filtered documents depending on their relevance to the query.

4.1. Dimensional filtering

One simple way to carry out the filtering is to use the Boolean operators (AND / OR) on the query dimensions. We think that this way can be a constraint for the user, especially when he has doubts, uncertainty, or has some priorities on dimensions of his query. Thus, we propose to use some criterions on the query dimensions in order to have more precision on the user need. Three criterions are thus proposed: "*obligatory*", "*optionally*", and "*priority*".

One dimension marked *obligatory* in a query must appear in the retrieved documents, while an *optional* dimension can appear or not. These criterions can surpass the limits of using the AND/OR operators [16]. It is possible that the user can not use these two criterions but in contrary, has some priorities on dimensions of his query. Thus we propose to use the criterion of *priority* allowing the user to give a priority value between 1 and m, where m is the number of all dimensions present in the query. Hence, a dimension having a priority j must appear in the retrieved documents, else, the dimension having a priority $j + 1$ must appear in the retrieved documents.

Finally, for each query dimension q_i, a criterion is added. The query dimension is thus represented as follow: $q_{i(criterion)}$, where criterion can be "*obligatory*", "*optionally*" or "*priority=value*".

The dimensional filtering consists to conserve only documents that respect the criterions added to the query dimensions. For example, for a query Q containing three dimensions, the sub queries Q_1, Q_2, and Q_3 are constructed. If the user decides that dimensions 1 and 2 are *obligatory*, and dimension 3 is *optionally*, we obtain a query represented as follow: $Q = \{Q_{1(obligatory)}, Q_{2(obligatory)}, Q_{3(optionally)}\}$. This implies that a relevant document must contain the dimensions 1 and 2, and eventually, the dimension 3. Thus, we filter the document collection and we obtain a non-ranked document set D_f that respects the prcised criterions. In order to return, for each query, one ranked document list we use a second technique that we describe in the next section.

4.2. Ranking technique

We rank the documents set D_f in order of relevance by using the VSM. We notice that a document is represented by a set of document dimensions, each one described by a set of concepts. Thus, to evaluate the relevance of a document D to a query Q, we compute the similarity $Sim(D, Q)$ between them by taking into account the similarity between all the dimensions that they share (cf. formula 5).

$$Sim(D, Q) = \frac{1}{m} \sum_{i \in [1,m]} Sim_{dim}(d_i, q_i) \quad (4)$$

- $Sim_{dim}(d_i, q_i) \in [0, 1]$: the similarity between a query dimension q_i and a document dimension d_i. It is computed by the cosine of the angle between the vectors $\overrightarrow{d_i}$ and $\overrightarrow{q_i}$ representing respectively d_i and q_i. This similarity is equal to 1 if q_i and d_i share the same concepts, and 0 if they do not share any concept;
- m: the number of dimensions in Q.

5. Experimental evaluation

The goal of our experiments is to evaluate the impact of taking into account dimensions on the mean average precision (MAP) of the IRS. We also evaluate the impact of using the criterions on the query dimensions. In the current experience, we do not set up the multi-dimensional indexing. We only set up the multi-dimensional querying. The evaluation consists to compare the result obtained by our approach to those obtained by the VSM.

5.1. The corpus and the external resource

As part of the Cross Language Evaluation Forum (CLEF), the ImageCLEF-2005 track [11] that promotes cross language image retrieval has a Medical Image Retrieval (MedIR) task in 2005. The test collection ImageCLEFmed-2005 contains 50,026 images with annotations in XML format. The majority of the annotations are in English but a significant number is also in French and German, with a few cases that do not contain any annotation at all. The 25 queries of the ImageCLEFmed-2005 base have been formulated with example images and short textual descriptions. For the current experience, we used only the English part of he ImageCLEF-2005 collection.

We used the UMLS (Unified Medical Language System) both as an external resource for conceptual indexing, and also as a reference to define dimensions. UMLS, a medical meta-thesaurus, is the result of fusion of many resources (thesaurus). UMLS contains 170 relation types between its concepts. All its concepts are organised, through a hierarchy, in 135 categories called "semantic types" and forming the semantic network. We use this structure to define the dimensions in the medical domain. For the indexing, we used the XIOTA experimental system [9].

5.2. Conceptual indexing

The conceptual indexing is a mean to take into account the dimensions during the IR process. As detailed in our previous work, this process is very difficult to set up [17]. Indeed, we made the hypothesis that only terms present in UMLS and retrieved, with lexical variation in medical text, make it possible to identify one concept[2]. To associate a term to a corresponding concept, we tested some techniques taking into account the size of each term. In order to reduce terms ambiguity and consequently improve the mapping, we carried out some filtering on document text and/or on the meta-thesaurus

[2]This hypothesis is restrictive because the terminology of UMLS does not cover all possible textual forms.

Table 1. Results using dimensions filtering and criterion on dimensions

	LTC		DFR	
	MAP	%	MAP	%
H1	0.222	+4.47%	0.2606	+2.71%
H2	0.2158	+1.55%	0.249	-1.88%
H3	0.2253	+6.02%	0.2606	+2.71%
H4	0.2279	+7.24%	0.27	+6.42%
H5	**0.2655**	**+24.94%**	**0.2897**	**+14.89%**

(e.g. eliminate some specific thesaurus from UMLS (those that are not relevant for our task).

For indexing, we use two weighting schemes: LTC and DFR [1]. Based on conceptual indexing, these two schemes give respectively a Mean Average Precision (MAP) of 0.2125 and 0.2537. In the following sections, these two results are called the *baseline*.

Results show that concept's extraction based on all terms independently of their size give better results than matching based of longer terms. Indeed, the extraction based only on longer terms is very precise, but also gives a lower recall. We also notice that filtering techniques can improve result and surpass those obtained during word-based indexing. Indeed, these filtering reduce ambiguity during the concept-term matching. Finally, despite the incomplete concept extraction, concept-based indexing allows to surpass the word-based indexing [17].

5.3. Multi-dimension filtering

In the ImageCLEFmed-2005 base, we have noticed, from the queries, the presence of three dimensions: *Anatomy*, *Pathology*, and *Modality*. We defined these dimensions through the semantic network of UMLS. The following semantic types of UMLS define them respectively:

- *Anatomy*: "Anatomical Structure", "Body System", "Body space or Junction", "Body Location or Region";
- *Pathology*: "Disease or Syndrome", "Finding", "Injury or Poisoning";
- *Modality*: "Diagnostic Procedure", "Manufactured Object".

In order to evaluate the impact of taking into account dimensions, we compare the results obtained here with the *baseline*. To carry out the filtering by dimensions, we have made five implicit hypotheses using different criterions on the query dimensions. Obtained results are presented in Table 1 where rows correspond to the hypotheses, and values correspond to the results and their variation rates compared to the *baseline*. Here we present the hypotheses.

H1: *Relevant documents include all the three query dimensions (if they exist in the query).* In this case, the request is presented as follows: $Q = \{Anatomy_{(obligatory)}, Pathology_{(obligatory)}, Modality_{(obligatory)}\}$. This hypothesis improves the result both for LTC and DFR. By observing the documents of the collection, we noticed that the *modality* dimension is not clearly stated in the documents. Indeed, the reports generally described a lesion on a part of the body and information on the type of image is often implicit. For this reason, we prefer the following hypothesis:

H2: *Relevant documents include at least one of the three query dimensions (if they exist).* This hypothesis improves the result for LTC, but causes a slight decrease of the result for the DFR.

H3: *Relevant documents contain the anatomy dimension present in the query*. By forcing only the "anatomy" dimension, we obtain a better result (+6.02%) in LTC and (+2.71%) DFR. We think that the result is better when we force any dimension and it seems that the dimensions are not equivalent. The anatomy is probably important because it is discriminating and non ambiguous, while pathology is more ambiguous (e.g. fracture of a cranium, fracture of a finger, etc.). Thus, we prefer the following hypotheses:

H4: *Relevant documents contain the anatomy, or else the pathology, or else the modality*. In this case, the request is represented as follow: $Q = \{Anatomy_{(priority=1)}, Pathology_{(priority=2)}, Modality_{(priority=3)}\}$. This hypothesis proposes an importance order on dimensions. We still obtain an increase in performance. Finally, and as the modality is not always present in documents, we propose the following hypothesis:

H5: *Relevant documents contain the anatomy and the pathology dimensions*. Thus, we obtain our best result: +24.94% (LTC) and +14.89% (DFR).

The efficiency difference between the dimensions can be explained by the fact that our technique of dimensions identification is not reliable[3]. Results show that taking into account query dimensions can enhance average precision. Actually, our approach allows to structure query, and thus precise it. Result obtained after the filtering by dimensions is complementary to results obtained by conceptual indexing. Indeed, the conceptual representation makes it possible to identify the query dimensions. The multi-dimensional filtering is a way to surpass the limits of the VSM that does not take into account relations between concepts of each vector and thus ignores the semantic content of document/query.

6. Conclusion and future work

In this paper, we proposed a new approach to solve multi-dimensional queries. First, we defined domain dimensions through external resources. Then, using a conceptual indexing and based on the defined domain dimensions, we identified dimensions from documents and queries in order to represent their semantic content. Thus, we proposed a new indexing language that takes into account the dimensions for better interpreting and representing the semantic document content. We also proposed a new query language that takes into account the dimensions for a better interpretation of the user needs and to represent the semantic content of a query.

Through an experimental evaluation on the ImageCLEFmed-2005 collection, we evaluated the filtering part of our approach. We set up the query module and show that our approach leads to an improvement of the mean precision by about 25%.

The results obtained so far encourage us to explore further the multi-dimensional approach. In the near future, we will implement a testing framework to conduct experi-

[3]We should verify manually the extraction and estimate a percentage of reliability.

ments on the entire approach. We will also study how our approach can be generalized to corpuses covering several domains. For this purpose we will introduce a notion of dimension relevance to evaluate how well a dimension describes the content of a document.

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Towards a standard protocol for community-driven organizations of knowledge

Chao Zhou, Christophe Lejeune, Aurélien Bénel
Laboratoire Tech-CICO, Institut Charles Delaunay (FRE CNRS)
Université de Technologie de Troyes

Abstract. This paper deals with the "Web 2.0", where every user can contribute to the content, "harnessing collective intelligence". After studying what makes the success of services like *Google Base*, *Del.icio.us* and the *Open Directory Project*, we propose a unifying "REST" protocol for this kind of community-driven organizations of knowledge. The aim is to make the collaboration possible beyond the boundaries of the software and of the resulting communities.

Keywords. Web 2.0, Communities, Knowledge Management, REST Web services

Introduction

The future of the Web was planned to be a *Semantic Web* with "content that is meaningful to computers" **[2]**. What we got instead is a *Web 2.0*, where every user can contribute to the content, "harnessing collective intelligence" **[14]**.

One should note that the move is not only from a formal semantics to a social one, but also from an innovation process lead by a consortium to a new one lead by independent socio-economic actors. The drawback of such a process is the resulting "babelization" between the different software services which makes it difficult to collaborate between the different user communities.

In the following pages, we will focus on community-driven organizations of knowledge. After studying what makes the success of *Google Base*, *Del.icio.us*, and the *Open Directory Project*, we will propose a unifying infrastructure for this kind of services.

1. Success stories

1.1. Google base

Google Base[1] is a "beta" service by Google which allows anybody to:

- Create an item of any type and describe it,
- Look for items satisfying to criteria.

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[1] http://base.google.com/

This service is intended to become *the* worldwide database for any type of items (even scientific ones like genes). For now, it is mainly used for classified ads (dating, housing, used cars…).

In fact, the data structure of *Google Base* reminds the one of the old *Machine Readable Catalogue* (*MARC*, still in use in public libraries) in the way it is "schema neutral". As *MARC* came in different "flavors" (*LCMARC*, *UKMARC, UNIMARC*…) chosen by librarians to fit their books and patron needs **[10]**, Google Base allows the user to use any attribute names (existing or new ones) to fit her item type and her needs (cf. Fig.1).

Nevertheless, the "report bad item" feature could indicate an interesting gap between the social process involved in *Google Base* and the library sciences goal of objectivity. That could be the reason why this universal database is in fact used only when the user *owns* the item (cf. Fig.1) and therefore is the only person who can describe it.

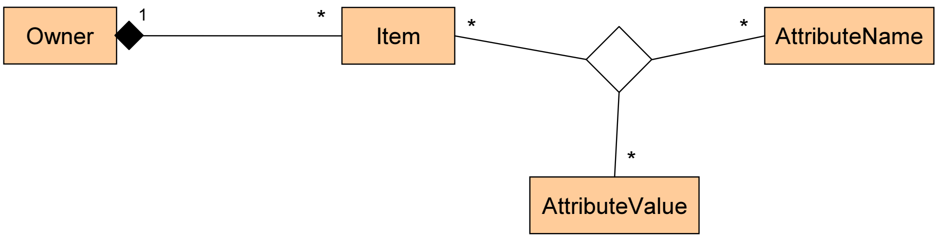

Fig. 1 – Reverse engineering of *Google Base* (UML class diagram)

1.2. Del.icio.us

Del.icio.us[2], a service first created as a hobby and now owned by *Yahoo!*, allows anyone to:

- Keep a bookmark of a web item and describe it with free keywords (called "tags"),
- Share them with other users,
- Discover new items by browsing popular and related tags,
- Make one's own description to existing items.

Del.icio.us aims at creating a directory of web pages by putting together a bunch of personal bookmarks. In order to gain objectivity, they had chosen a democracy-like model where every opinion can be expressed but is considered to be significant only when it is shared by a lot of people.

In a way, the data structure of *Del.icio.us* (and other similar "folksonomies" like *Flickr*) reminds the one from *Xanadu*: "the original hypertext project" **[13]** in which users were able to reuse fragments and links in different "documents". But the difference between a "document" and a "tag" is that a tag is not *owned* by a user. The tag is collective and therefore only the statement saying that a document is described by a tag is attributed to a user (cf. Fig.2). But, are the tags "mydog" and "todo" really collective [11]? Do these tags even mean something in a shared place? In the same way, does "apple" mean the same thing for geeks, cookers and New Yorkers? To be really collective, tags should be defined inside a "viewpoint": a *language* used by a community. Then it would not be the same "apple" tag, just as "pain" is not the same in English and in French.

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2 http://del.icio.us/

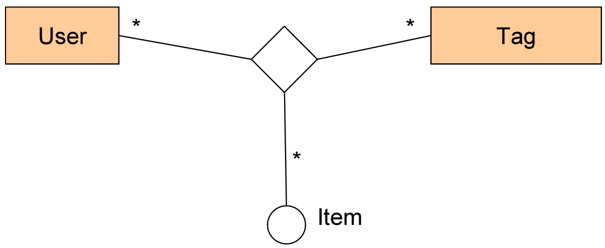

Fig. 2 – Reverse engineering of *Del.icio.us* (UML class diagram)

1.3. The Open Directory Project

As all directories, the *Open Directory Project*[3] is a tool to help users locating information on the Internet. The website home page of the project proposes some general topics as a starting point of the query. Crawling from general topics towards more and more specialized rubrics, the user can specify her query so that (and up to) she will find a list of websites containing the information he is searching.

A directory is thus a hierarchical structure of categories. The main top category contains all the others (it stands as the front menu of the home page). This menu features a dozen of general topics (such as arts, sciences or health). Each of these general categories contains a branch of imbricated sub-categories and websites references.

Leaving the user's point of view for the designer's one, the *Open Directory Project* is a community of volunteer editors. Each editor maintains (at least) one category (which means that editors are thematically skilled). She is responsible for all the content of this category. This includes recording websites, describing the category, inserting sideways links, and managing all subsequent subcategories. The core business of the editor is to provide the directory with website references. This includes, for each recorded web sites, to insert an address (URL), a title and a short text describing its content. Editors also redact the description for the rubric they are in charge and insert sideways links from category (these links are described hereunder).

The fact that they can manage subcategories means that scopes of action differ from one person to another. This situation leads to propose that the thematic tree is coupled by a social tree (with social issue in selected cases).

The aim of the community (as a whole) is to propose an alternative to other information retrieval tools. The ultimate purpose is to provide users with a tool giving more adequate results than search engines. The very idea resides in that:

- The path of the categories situates and contextualizes the information (contrary to keywords query introduced in the input field of a search engine front page),
- Each reference is described by an expert.

[3] http://www.dmoz.org/

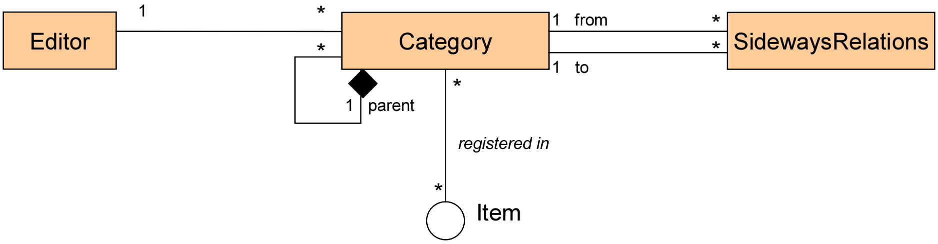

Fig. 3 – Reverse engineering of the *Open Directory project* (UML class diagram)

Founders of directories face two problems. The first is related to human resources, the second with tree structure. Given that directories databases are constructed by humans (contrary to search engines that are computer-processed), these projects need large teams of skilled specialists. This core weakness is solved in the case of the *Open Directory Project*, thanks to its organization in a community of benevolent contributors (as free software programmers).

The second problem is the tree structure of the database front end. Even if this shape organizes the information, it can yield to locate some rubrics that concern close topics in different branches. This raises usability problems. Used to this question (through similar tools as thesauruses), information scientists solve the issue with sideways relations that allow the user to glance through the database. Known as "related terms", these horizontal bridges are indicated by the "see also" heading **[1]**. Directories feature also such relations. In the *Open Directory Project*, they are of three kinds: related categories, alternate language and symbolic links.

As signaled by the name, related categories implement a relation similar to the "see also" link from thesauruses. The complete path and name of the target categories are featured and the target (sister) category is considered to cover a close theme to the origin category. The relation can be reciprocal but this is not necessary.

Alternate language links relate categories that cover the same theme in different language. This means that the global tree of the *Open Directory Project* includes duplicate hierarchies in each language. This division was not in the original model but was introduced when more and more non-English members join the project. At a first stage, language branches were created and relations between them were indicated with the related categories features. Then (late 2000), the alternate language link was introduced. The link only indicates the name of the language to which the target category belongs (only one equivalent by language is permitted).

The symbolic links are sideways relations that include a peculiar semantics. The target category can be considered as a subcategory (a child) of the origin category. Symbolic links are listed among other effective sub-rubrics and are signaled and distinguished from the latter by a trailing "at sign" (@). Neither the path, nor the name of the target category is featured; the name of the symbolic link is chosen by the indexer.

2. Towards a unifying infrastructure

The following section describes the *HyperTopic* protocol, named from the underlying data model: the *HyperTopic* Model **[6]**. Our goal is to propose this protocol as a standard for services aiming at community-driven organizations of knowledge.

The protocol is designed in a "REST" style to achieve visibility, reliability and scalability. REST is an acronym standing for "Representational State Transfer". REST is not a standard; it is an architectural style for distributed network systems **[9]**. The motivation of REST was to find out which characteristics made the web successful, and use these characteristics to guide the evolution of the web **[7]**. An important rule in REST is that every resource should have one URI. The components in the distributed system could use a set of HTTP methods (POST, PUT, GET, and DELETE) to manipulate those resources. Representations in REST style protocol usually are HTML or XML files that contain information and links to other resources. The components of the distributed system can navigate from one state of representation to another state, simply by following the links.

2.1. Objects URI

One of the most important characteristics of REST is about exposing resources through URIs **[12]**. There are different types of object in the *HyperTopic* model (Fig.4): Actor, Viewpoint, Topic, Entity, and Attribute. All of those should be uniquely addressable through URIs. A client could realize representational state transfer from one object to another object (e.g. from viewpoint to topics, or from topics to entities) by following those URI.

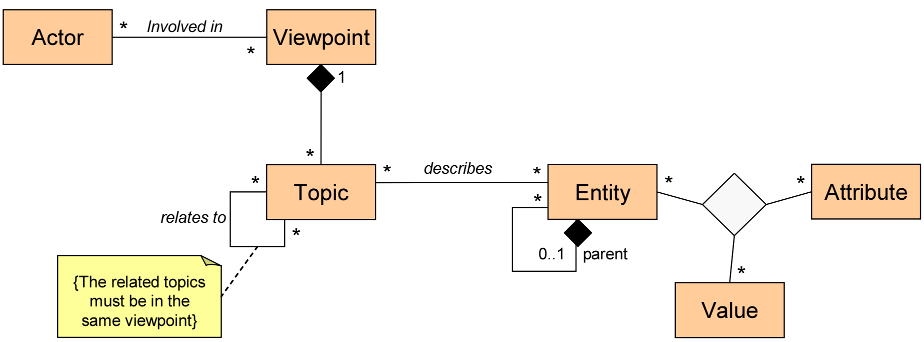

Fig. 4 – The *HyperTopic* Model (UML class diagram)

Actor

The actors involved in reading and writing viewpoints are identified by a login. Assuming there were on www.example.org an actor whose login is 'linuxfans', its URI would be: *http://www.example.org/actor/linuxfans/*

Viewpoint

According to user's roles, a user could visit or manage one or several viewpoints by their URI. Assuming there were on www.example.org a viewpoint which ID is 1, its URI would be: *http://www.example.org/viewpoint/1/*

Topic

Every topic must belong to one and only one viewpoint. The URI of that topic will contain the viewpoint identifier and use hierarchical structure to represent the relationship between viewpoint and topic. The URI of topic #2 from viewpoint #1 would be: *http://www.example.org/viewpoint/1/topic/2*

Entity

Every entity should have one URI. An entity is defined by a persistent name. For example, the URI of the "Amaya" software entity would be:
http://www.example.org/entity/AMAYA/

Attribute value

An attribute value is identified by its name and its value. For example, the URI of 'INRIA' as an 'author' is: *http://www.example.org/attribute/author/INRIA/*

2.2. XML structure

In the *HyperTopic* protocol, software and service transfer data in XML streams. The following tables describe the *HyperTopic* document format. Those tables use standard XPath notation, slashes to show the element hierarchy, and an "at sign" indicates the attribute of an element.

Actor

XPath	Cardinality	Description
/actor/@name	Optional	Actor Name.
/viewpoint	*	Viewpoints which this actor could visit or manipulate
/viewpoint/@xlink:href	Required	Viewpoint URI

Viewpoint

XPath	Cardinality	Description
/viewpoint/@name	Optional	Viewpoint Name.
/viewpoint/actor	*	Actor which could visit or manipulate this viewpoint
/viewpoint/actor/@xlink:href	Required	Actor URI
/viewpoint/topic	*	Topics which are linked to the viewpoint.
/viewpoint/topic/@xlink:href	Required	Topic URI.

Topic

XPath	Cardinality	Description
/topic/@name	Optional	Topic Name.
/topic/viewpoint	1	Viewpoint which the topic belongs to.
/topic/viewpoint/@xlink:href	Required	Viewpoint URI.
/topic/relatedTopic	*	Topics linked to the current topic Note: The related topics should be in the same viewpoint.
/topic/relatedTopic/@relationType	Optional	The relation type between the current topic and the related topic.
/topic/relatedTopic/@xlink:href	Required	Related topic URI.
/topic/relatedTopic/@status	Optional	Status of related topic (active or inactive).
/topic/entity	*	Entities described by the topic.
/topic/entity/@xlink:href	Required	Entity URI.
/topic/entity/@status	Optional	Status of the link to the entity (active or inactive).

Entity

XPath	Cardinality	Description
/entity/attributeValue	*	Attribute values which belong to the Entity.
/entity/attributeValue/@xlink:href	Required	Attribute value URI.
/entity/attributeValue/@status	Optional	Status of the link to the attribute value (active or inactive).
/entity/topic	*	Topics which describes the Entity.
/entity/topic/@xlink:href	Required	Topic URI.
/entity/topic/@status	Optional	Status of the link to the topic (active or inactive).

Attribute Value

XPath	Cardinality	Description
/attributeValue/entity	*	Entities described by the attribute value.
/attributeValue/entity/@xlink:href	Required	Entity URI.
/attributeValue/entity/@status	Optional	Status of the link to the attribute value (active or inactive).

2.3. HTTP Methods and Status Codes

In a RESTful protocol, a client can use GET method to retrieve resources. Use POST method to create a new resource with new URI. For example, a client can send POST request with XML payload to URI "/viewpoint/" to create a new viewpoint. After the successful execution, the server will return a newly created URI with status code 201. The PUT method is used to create a new resource or to replace an existing resource with URI. If the request-URI refers to an existing resource, the server will replace the resource with the enclosed resource. If the request-URI does not point to an existing resource, the server would create the resource with that URI. In the *HyperTopic* protocol, to trace the changes, the DELETE method does not actually delete the resource but just inactivate it.

The following table describes what the status codes mean in HTTP.

Code	**Details**
200 OK	The request has succeeded.
201 CREATED	The request has been fulfilled and resulted in a new resource being created.
205 RESET CONTENT	Modification of a resource has succeeded.
400 BAD REQUEST	The request could not be understood by the server due to malformed syntax.
403 FORBIDDEN	The server understood the request, but is refusing to fulfill it.
404 NOT FOUND	The server has not found anything matching the Request-URI.
500 INTERNAL SERVER ERROR	The server encountered an unexpected condition which prevented it from fulfilling the request.

The following table gives the typical status codes in the *HyperTopic* protocol that could be returned.

Actor

	Description	**200**	**201**	**205**	**400**	**403**	**404**	**500**
GET	To get actor							
PUT	To create or update actor.							

Viewpoint

	Description	**200**	**201**	**205**	**400**	**403**	**404**	**500**
GET	To get viewpoint list. To get viewpoint							
POST	To create viewpoint.							
PUT	To update viewpoint.							
DELETE	To trace changes, we do not really delete the viewpoint, and instead we just inactivate it.							

Topic

	Description	200	201	205	400	403	404	500
GET	To get topic.							
POST	To create topic. To update topic.							
DELETE	To trace changes, we do not really delete the topic; instead we just inactivate it.							

Entity

	Description	200	201	205	400	403	404	500
GET	To get entity.							
PUT	To create entity or update entity.							

Attribute Value

	Description	200	201	205	400	403	404	500
GET	To query attribute value							
PUT	To add new attribute value or update attribute value.							

2.4. Other resources

Although a client can enter the framework by actors URI, it could also do it by other special resources URIs. Those URIs will be used through GET methods only.

A client could use the following URIs to know the existing viewpoints: *http://www.example.org/viewpoint/*

The following table shows the format of viewpoint list:

XPath	Cardinality	Description
/viewpoints/viewpoint	*	Viewpoint
/viewpoints/viewpoint/@xlink:href	Required	Viewpoint URI

To know the existing attribute names, a client would use the following URI: *http://www.example.org/attribute/*

The following table shows the format of attribute list:

XPath	Cardinality	Description
/setOf/attributeName	*	Attribute name.
/setOf/attributeName/@xlink:href	Required	Attribute name URI.

A client would use the following URI in order to know the existing values for an attribute name: *http://www.example.org/attribute/author/*

The following table shows the format of attribute list:

XPath	Cardinality	Description
/attributeName/value	*	Attribute values.
/attributeName/value/@xlink:href	Required	Attribute URI.

A client could query an attribute. The query URI consists of an attribute URI and a SQL-like clause. For example: in order to find out the entities whose "type" is "Software", the URI would be:
http://www.example.org/attribute/type/upper(value)='SOFTWARE'

XPath	Cardinality	Description
/setOf/attributeValue	*	Attribute values corresponding to the clause.
/setOf/attributeValue/@xlink:href	Required	Attribute value URI.
/setOf/attributeValue/entity	*	Entities described by this attribute value.
/setOf/attributeValue/entity/@xml:href	Required	Entity URI.

Conclusions and future works

This paper challenges the future of the Web, to be related with socially (rather than ontologically) organized knowledge. We started with the description of three collaborative actual projects. Even though composed of volunteer lay people, these three communities exhibit peculiarities in the way knowledge is organized inside them. Our challenge was to propose a unified infrastructure for these. Based on the *HyperTopic* data model, we introduced the *HyperTopic* protocol to reach this aim.

After having implemented the server side of the project in *Argos,* we are currently working on the client side. This work is achieved by modifying two existing software: *Agorae* **[5]** and *Porphyry* **[4]**. The first one is a virtual marketplace allowing users to propose and describe material and immaterial goods (Fig. 5). The later is a digital library where scholars can publish and interpret differently document corpora (Fig. 6). Both of these software systems have been used by experts sharing their knowledge in collaborative project. Each user can construct her own viewpoint. A viewpoint can also be managed by groups of agreed individuals. This assumes that exposing concurrent view could fruitfully regulate and federate the community **[15]**.

Once *Agorae* and *Porphyry* are adapted to conform to the *HyperTopic* protocol, we are willing to propose this protocol as a standard draft to a normalization organization.

Fig. 5 – “YEPOSS: Yellow pages for open source software” **[6]** (*Agorae* screenshot)

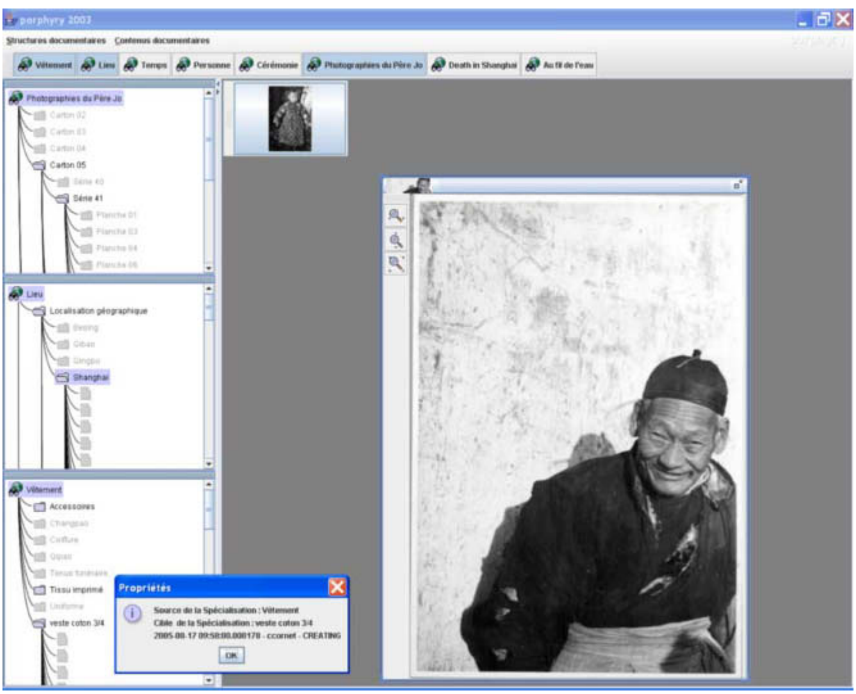

Fig. 6 – “China in the 30s: Making history from photographs” by C. Henriot and C. Cornet from the “Institut d’Asie orientale” (*Porphyry* screenshot)

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An IR model based on a sub-tree representation

Mohand Boughanem, Mustapha Baziz
IRIT-Université Paul Sabatier
118 route de Narbonne, 31062 Toulouse
{boughane, baziz}@irit.fr

Abstract. The paper proposes an approach to information retrieval based on the use of a structure (ontology) that is used both for document (resp. query) indexing and query evaluating. The conceptual structure is hierarchical and it encodes the knowledge of the topical domain of the considered documents. It is formally represented as a tree. In this approach, the query evaluation is based on the comparison of minimal sub-trees containing the two sets of nodes corresponding to the concepts expressed in the document and the query respectively. The comparison is based on the computation of a degree of inclusion of the query tree in the document tree. Experiments undertaken on MuchMore benchmark showed the effectiveness of the approach.

Keywords. Concept, ontology, concept based retrieval, document completion retrieval.

Introduction

Textual Information retrieval (IR) is based on keywords or expressions (generally associated with importance weights) extracted from documents and employed as the index keys for both document and query representations: both are expressed in terms of (weighted) keywords [23]. However, keywords may have different levels of granularity. For instance, "earth science" is a more general expression than "geology". Thus, some may refer to general topics while others are more specific descriptors. It may also happen that terms which can be used for describing the general topic(s) of a document are not so much present in the document. Still they are useful for classifying the document and referring to its contents.

Recently, an increasing number of approaches to IR have defined and designed IR models which are based on concepts rather than keywords, thus modeling document representations at a higher level of granularity, trying to better the meaning and the context of the keywords rather than the rather than the "string words" that occur in the documents. These efforts gave raise to the so called concept-based Information retrieval, which aims at retrieving relevant documents on the basis of their meaning rather than their keywords. The main idea at the basis of conceptual IR is that the meaning of a text depends on conceptual relationships to objects in the world rather than to linguistic relations found in text or dictionaries [25]. To this aim, sets of words, phrases, names are related to the concepts they encode [14].

In this paper, a concept-based information retrieval is proposed. Based on the existence of a conceptual hierarchical structure which encodes the contents of the

domain to which the considered collection of documents belongs, both documents and queries are represented as weighted trees. The evaluation of a conjunctive query evaluation is then interpreted as computing a degree of inclusion between sub-trees.

The ontology-based description of the contents of the documents takes into account the semantic equivalences between concepts, as well as the basic principle stating that if a document explicitly heavily includes some terms, it also concerns to some extent more general concepts. This latter point is handled at the technical level by a completion procedure which assesses positive weights also to terms which do not appear directly in the documents.

The paper is organized into five main sections. In section 1, related works related to the concept-based IR are overviewed. Section 2 introduces the proposed concept-based representation of documents. In section 3 the process of the conceptual query evaluation is described. The results of the experiments are reported and discussed in section 4. Finally, concluding remarks with some prospects are given in section5.

1. Concept-Based IR: Related Works

The primary objective of the research in information retrieval is to define models, which allow designing effective IR systems, i.e. systems able to retrieve from the considered archive the documents concerned with the topics relevant to a user and expressed by a user query. The production of effective retrieval results depends on both subjective factors, such as the users' ability to express their information needs in a query, and the characteristics of the IR system. The indexing process plays a crucial role in determining the effectiveness of an IR system: in fact, to provide IR systems with powerful query languages or sophisticated retrieval mechanisms is not sufficient to achieve effective results if the representation of documents oversimplifies their information content. The most used automatic indexing procedures are based on term extraction and weighting. However, keyword-based retrieval models have several limitations; an important one is that they do not take into account the topical structure and content of documents, thus preventing concept-oriented document representation and query formulation.

Recently, some approaches have been proposed to concept-based Information retrieval. In concept-based IR, sets of words, names, noun phrases are mapped into the concepts they encode [12]. By these models, a document is represented as a set of concepts: to this aim a crucial component is a conceptual structure for mapping concepts to document representations. Conceptual structures can be general or domain specific. In [12] an analysis of conceptual structures and their usage to improve retrieval is presented. Conceptual structures include dictionaries, thesauri and ontologies, and they can be either manually or automatically generated or they may pre-exist [13]. WordNet and EuroWordNet are examples of (thesaurus-based) ontologies widely employed to improve the effectiveness of IR systems.

A conceptual structure can be represented using distinct data structures: trees, semantic networks, conceptual graphs, etc. In [18] and [25], the use of conceptual graphs for representing documents and queries is discussed. The authors propose a method for measuring the similarity of phrases represented as conceptual graphs. In [12], the authors propose an indexing method based on the use of WordNet synsets: the vector space model is employed, by using synsets as indexing space instead of word forms. In a similar spirit in [6], the authors have advocated the use of possibilistic

ontologies, distinguishing between specialization and approximate synonymy relations, in information querying.

In [7], a concept based information retrieval approach based on the use of a thesaurus is proposed. In [16], an approach to detect the topical structure of a set of documents is presented. Probabilistic latent semantic analysis has been employed as a mean to define conceptual structures; it applies an unsupervised learning technique to define a semantic (topic-based) language model [1], [20].

In this paper, we do not face the problem of generating a conceptual structure, we take as a preliminary assumption the existence of a conceptual structure (more precisely an ontology) describing the contents of a considered document collection. This structure is a hierarchical tree, as it will be explained in section 4. In the next section, we will describe how concepts are extracted and weighed from documents.

2. Concept-Based IR driven by Ontology

The principle of the proposed approach aims at representing both documents and queries by means of sub-trees. A document/query is represented by a set of concepts corresponding to nodes in the hierarchical structure of ontology. Each node in the resulted sub-trees corresponds to a disambiguated term from a document/query that matches one concept of ontology. Sub-trees are obtained by considering only the "subsumption" relation represented in our case by a classical is-a relation (hypernymy). The idea behind this representation is to complete the document/query description by possibly adding intermediate nodes in order to complete these representations by concepts that do not appear explicitly in a document and/or a query but that deal somewhat with the same topic. More details regarding the approach are given in the next sections.

2.1. Concept-based representation of documents and queries

In the proposed approach, the query evaluation of is mediated by an ontology made by a unique tree-like hierarchy H of concepts, which are supposed to be sufficient for describing the contents of the considered documents with an appropriate level of accuracy. Leaves in H can be thought as simple keywords, i.e. keywords expressing specialized concepts, while other nodes refer to keywords, which are labels of more general concepts. Edges in this hierarchy represent the classical *is-a* link.

Both documents and queries are supposed to be interpreted or expressed in terms of labels of nodes of *H*, possibly in association with weights.

Let d be a document. Each document d is identified by means of a set of pairs $R_d = \{(w_i, \alpha_i), i = 1, k(d)\}$ where w_i is a key word or phrase taken from d that corresponds in a univocal way to a concept c_i (node n_i) from H and α_i is its importance weight (index term weight) k(d) is the number of terms in document *d*.

The first step of the approach is to compute the projection H_d of **d** on H, in the following way:

a weighted subset $N(H, d)$ of nodes of H, namely $N(H, d) = \{(n_j, \gamma_j), j = 1, m(d)\}$ where for any node n_j, there exists w_i in $d = \{(w_i, \alpha_i), i = 1, k(d)\}$ such that $n_j = w_i$, and n_j is known as the *most appropriate concept* (or node) [2] that represent better w_i in the conceptual structure H, and then we take $\gamma_j = \alpha_i$. m(d) is the number of nodes in H that

are equivalent to some terms in R_d. When several equivalent expressions w_i in H exist, the longest term is retained as described in section 5.2.1.

The second step of the approach is to build the minimal sub-tree H_d, of H which contains $N(H, d)$, where the weights associated with the nodes are those obtained at step i if the nodes belong to $N(H, d)$ and are 0 otherwise.

Let q be a query obtained by selecting a collection of labels (concepts) in H, with possibly an importance weighting, namely as a set $\{(l_k, \delta_k), k = 1, r(q)\}$. A query q is also modeled by a sub-tree H_q of H. Namely H_q is the minimal weighted sub-tree of H containing $\{(l_k, \delta_k), k = 1, r(q)\}$, keeping the weights δ_k, and putting 0 on the other nodes of H_q.

At these two stages the query and the documents are represented by sub-trees with weighted nodes.

3. Query evaluation

Query evaluation is based on the comparison of two weighted subsets of nodes of H, one corresponding to the query and the other to the current document. The relevance of the query with respect to the document is interpreted as an inclusion degree which evaluates to what extent a document includes all the features of the query.

Various implication connectives in the definition of the inclusion degree is discussed.

3.1. Comparison based on the minimal common sub-tree

The evaluation of a query q with respect to a document d, is performed in terms of a degree of relevance $rel_c(d; q)$ of d with respect to q computed as degree of inclusion of H_q into H_d, namely

$$rel_c(d; q) = f(\mu_{H_q^*}(n) \rightarrow \mu_{H_d^*}(n)),\ n \in H_E \qquad \mathbf{(1)}$$

where $\mu_{H_d^*}(n)$ (resp. $\mu_{H_q^*}(n)$) is the weight associated with node n in H_d^* (resp. H_q^*), and $\rightarrow$ is a multiple-valued implication connective expressing that all the concepts of the query should appear in the description of the document.

The usual way to interpret f function is to use a conjunction aggregation *min*. One may think of introducing equivalence connectives in place of implications in (1) for requiring that the topic of the document correspond exactly to the topic of the query. However, note that looking for exact matching may be dangerous: suppose we are looking for documents dealing with topic A (q=A) but there does not exist any document dealing with A without B (d=A, B); in such a case the exact matching strategy will give nothing. However, strict equivalence could be relaxed into approximate similarity by weakening the equivalence connective by means of a similarity relation.

A strict conjunctive evaluation, f=*min,* may be too requiring, and in information retrieval, "best matching" is usually preferred to exact matching. Therefore, a simple function that is known to allow best matching is the sum computed as follows, and that is also used in this paper:

$$\text{Sum : } rel_d\ (d; q) = \sum_{n \in H_E} \mu_{H_q{}^*}(n) \rightarrow \mu_{H_d{}^*}(n) \qquad \textbf{(2)}$$

3.2. Choice of an implication connective

Several choices can be considered for the implication → used in (1), depending on the intended semantics of the weights in the query. A usual way to interpret this implication in IR consists in using a similarity function. Another possible method, borrowed from the fuzzy approach is to consider the Lukasiewicz implication connective. More details concerning the use of more implications connective that have clear semantics in a retrieval context are discussed in [3] and [19] (another comparison is also described in [9] in a database context):

Lukasiewicz implication: $a \rightarrow b = \min (1, 1 - a + b)$

namely $a \rightarrow b = 1$ if $a \leq b$ and $a \rightarrow b = 1 - a$ if $b = 0$.

4. Experiments

The aim of the experiments is to evaluate the effectiveness of the concept-based approach proposed here compared to classical IR approach. Especially two main contributions described in the paper are evaluated:

- How good is the concept-based approach compared to the classical one?
- How good is the completion of documents and/or queries compared to the classical?

The classical approach used in these experiments is based on a vector space model which is implemented in the Mercure system [5].

Below, we detail the experiments settings.

4.1. Document collection

The test collection we used in these experiments is issued from the MuchMore project [5]. This collection contains 7823 documents (medical papers abstracts) obtained from the Springer Link web site, 25 topics from which the queries are extracted and a relevance judgment file which determines for each topic its set of relelant documents. These assesments were established by domain experts from Carnegie Mellon University, LT Institute.

4.2. Ontology

WordNet [17] is used as general purpose ontology. In WordNet, concepts are organized into taxonomies where each node is a set of synonyms (called synset) representing a single sense. Several semantic relationships between nodes are defined, denoting generalization, specialization, composition links, etc. We used only the concept hierarchy identified by the IS-A relation. Using WordNet as ontology needs specific setting. Indeed the first stage is concepts node identifying and the second is the document (query) completion. These two operations are details below.

As the collection deals with the medical domain, the question of the suitability of WordNet for this kind of collections could be asked. Statistics carried out over the collection show that the vocabulary of the documents of the collection is almost covered by WordNet: about 87% (respectively 77%) of terms used in documents (respectively queries) appear in WordNet.

4.3. Evaluation methodology

In order to evaluate our approach, two sets of experiments were carried out. The first set is based on classical indexing and the second is based on the approach proposed in this paper. In the classical approach, the documents were first indexed using a classical term indexing. It consists in selecting single words occurring in the documents, and then stemming these words using Porter algorithm [21] and at the end removing stop-words according to a standard list [23]. A weight is then assigned to each term following a kind of BM25 TF.IDF formula [4]. The same process is applied to queries. A vector-based model [4] is then used to retrieve documents. We used this run as a baseline.

In the concept-based approach, the documents and the queries are indexed using a concept based detection described in 6. The result of this stage is that each document (query) is represented by a set of weighted concepts (ontology nodes). Once nodes representing the documents (queries) are identified, the corresponding sub-trees, (Hd) and (Hq) are built by using the pruning method. In these experiments the number Nb of extra nodes to be added is set to 3. Once the document and the query sub-trees are built, the query evaluation is carried out. It is based on Lukasiewicz implication using two aggregation functions namely, min and sum. More over, in order to evaluate the impact of the completion approach we only evaluated the topical approach, the query independent approach. The contextual approach is not scalable.

The experimental method follows the TREC protocol [27]. For each query, the first 1000 retrieved documents are returned by the search engine and precisions are computed at different points P5, P10, P15 and P30 representing the mean precision values for the 20 used queries at the top 5, 10, 15 and 30 selected documents and MAP, the Mean Average Precision over the 20 queries.

4.4. Results and discussion

Table 1 evaluate the impact of the aggregation functions (min and sum), when used to compare queries and documents sub-trees. As it can be expected, the aggregation function has a great impact. Indeed one can notice the strict conjunctive is clearly less interesting than the sum method at all considered precision levels. In fact, this function which performs an exact matching is mostly adapted to Data Retrieval (a document is retrieved if and only if it contains all query terms), whilst best matching is used in information retrieval [26].

Table 1 comparison of classical vs. concept-based approach

Run	Precisions				
	P5	**P10**	**P15**	**P30**	**MAP**
Baseline	0.700	0.630	0.576	0.438	0.414
Min	0.420	0.310	0.233	0.190	0.144
Sum	**0.760**	**0.695**	**0.613**	0.438	0.409

This is confirmed in these experiments, when best matching operators are considered, namely sum. However, one notices that the classical approach is slightly better than the concept-based on MAP level but the concept approach outperform the classical at top level precisions (P5, 10 and 15). In fact, this has several reasons. The first one comes from the way the documents are indexed. Indeed only concepts belonging to the documents (queries) and the ontology are used as index term. Nevertheless, it is usually admitted in IR [2] that using only concepts from ontology as index term are not sufficient to cover all the items of the documents (queries). So, our index lacks of exhaustivity. This explains the slight decreasing of the MAP. But, as the concepts are more specific than single terms the index becomes more specific. This increases the precision at top documents. This is an interesting result. Indeed even though our weighting schema is quite rudimentary, our approach outperforms the classical one at top retrieved documents (with more than 10% improvement at P10).

5. Conclusion

The work developed in this paper lies within the scope of the use of ontologies to concept-based indexing in information retrieval. We have introduced an approach which models both documents and queries as tree-like ontologies where nodes are weighted. The query evaluation process uses fuzzy connectives.

The preliminary experiments carried out on an IR collection indicate that the proposed approach is viable in IR. The results showed that the concept-based approach outperforms the classical IR one based on vector space model. Future works will focus the evaluation of the concept-based approach on larger collection such the TREC collection [27].

Possible prospects within this work concern the use of the approach at inter-document level. Indeed, the sub-trees resulting from the projection of documents on ontology could be compared for thematization. Thus, one can assume that documents with closest sub-trees could be regarded as covering a same subject. It remains to define the intersection function between two sub-trees.

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Develop a novel methodology for strategic product portfolio management considering multi-objectives and operational constraints

Amy J.C. Trappey[a], Tzu-An Chiang[a], Charles V. Trappey[b], Jen-Yau Kuo[c]
[a]*Department of Industrial Engineering and Engineering Management, National Tsing Hwa University, Hsinchu (300), Taiwan; trappey@ie.nthu.edu.tw, Tel: +886-3-5742651, Fax: +886-3-5722204*
[b]*National Chiao TungUniversity, Hsinchu (300), Taiwan; trappey@cc.nctu.edu.tw*
[c]*RFID Technology Center, Industrial Technology Research Institute, Hsinchu (310), Taiwan; jykuo@irtr.org.tw*

Abstract. This paper applies the concept of concurrent engineering to develop a product portfolio management (PPM) methodology, which systematically analyzes product portfolio strategy at the beginning of the product lifecycle. This research adopts the approach of multi-attribution decision analysis to estimate the synthesized-performance value for each R&D project. Thus, the most plausible product portfolio can be concurrently derived during the early design stage to avoid investing and executing less ideal product R&D projects. We develop a new methodology for evaluating the resource requirements and the potential risks of product portfolios through applying the activity-group concept. In order to accurately estimate the revenue of a product portfolio, this research considers the levels of substitution among products in a given product portfolio. Finally, a case study of mobile phone PPM helps us demonstrate the efficacy of the methodology presented in the paper

Keywords. product portfolio management, enterprise resources, product development projects, concurrent engineering.

1. Introduction

Owing to fierce business competitions and shortened product life cycles, particularly in high technology sectors, new products must be designed and delivered to the market in a short period of time. According to Griffin (1997), approximately 32% of companies' sales today come from new products introduced in recent five years. This shows that it is very important for a company to stay competitive by continuously delivering new products successfully on the marketplace. However, there are usually more new product development projects available for selection than what can be undertaken within resources constraints of a firm (Archer and Ghasemzadeh, 1999). Facing high failure rate of new product introduction and enterprise resource constraint, it becomes crucial in establishing a systematic approach to evaluate new product development projects concurrently, i.e., to select the most appropriate product portfolio strategy and to allocate proper enterprise resources on the selected projects. Currently, many

companies lack a structured process for PPM (Ölundh and Ritzén, 2004). Hence, the objective of this research is to develop a novel analysis methodology of PPM.

2. Literature Review

In recent years, many high-tech companies that depend on new product development have paid more attention to PPM because product portfolio decision making will profoundly affect a company's long-term profitability and competitiveness. In order to support the selection of projects, Meade and Presley (2002) employ the analytic network process (ANP) model, which can take into consideration multiple criteria for evaluating R&D projects. Archer and Ghasemzadeh (1999) simplify the project selection process by developing an integrated framework that decomposes it into a flexible and logical series of activities. Dickinson et al. (2001) present a model developed for the Boeing Company to optimize a portfolio of product development projects. Owing to R&D project selection in an environment of uncertainty and ambiguity, Machacha and Bhattacharya (2000) develop a fuzzy-logic rule-based expert system to project selection.

3. The Framework of Product Portfolio Selection and Evaluation

Applying the concurrent engineering concept, this study presents an architecture of a product portfolio strategy analysis. Figure 1 shows an analysis process of the most appropriate product portfolio strategy in a systematic manner.

3.1 The dimensions and criteria for evaluating R&D project

Based on the result of literature review and the company interviews, this study creates a hierarchical structure of dimensions and criteria of R&D project evaluation as shown in Figure 2. This structure includes four dimensions, i.e., technology, risk, strategy and economics. Each dimension is evaluated in terms of its multiple criteria. In order to screen the best R&D projects, each alternative must be assessed with respect to each criterion of all dimensions.

The evaluation of performance criteria can be divided into two categories, i.e., qualitative evaluation and quantitative evaluation. Profits of products and patents and the time-to-market risk belong to the quantitative evaluation. Others belong to the qualitative evaluation. In this study, the qualitative evaluation provides seven linguistic expressions, i.e., 'extremely bad', 'very bad', 'bad', 'fair', 'good', 'very good', 'excellent'. Each linguistic variable can correspond to the triangular fuzzy numbers as shown in Table 1.

Table 1. Linguistic variables correspond to the triangular fuzzy numbers

Linguistic variables	Extremely bad	Very bad	Bad	Fair	Good	Very good	Excellent
Triangular fuzzy numbers	0	15	30	55	70	85	90
	0	30	45	65	80	90	100
	20	45	60	75	90	95	100

With regard to quantitative criteria, we employ net present value (NPV) method to calculate the profits of the products and patents. In regard to the risk evaluation of

technical success, this study divides a general product development process into several independent activity groups. Each activity group contains some R&D activities. In order to make every activity group independent to each other, the project managers need to establish clearly design guidelines and product specifications in advance. Hence, the risk of technical success of a project can be expressed as follows.

$$R_p = P(AG_1^p \cap AG_2^p \cap \cdots \cap AG_n^p) = P(AG_1^p) * \cdots * P(AG_n^p) = \prod_i^n P(AG_i^p) \quad (1)$$

where R_p is the risk of a new product development project. AG_i^P is the event that the specific R&D group (i) achieves its objectives. According to characteristics of the industry and R&D abilities of a company, top managers decide risk intervals of technical success of a project with corresponding to linguistic variables. Hence, the evaluation of technical success risk can be obtained.

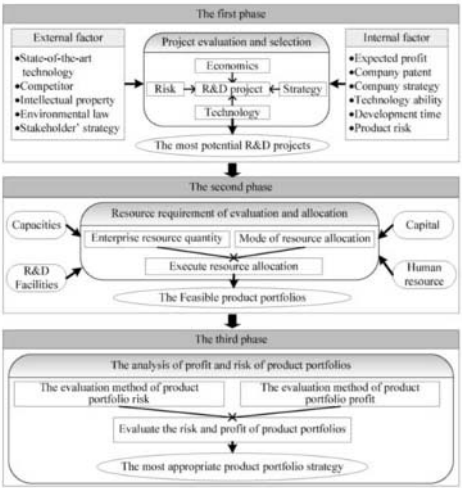

Figure 1. The analytical framework for selecting product portfolios.

Figure 2. A hierarchical structure of factors of R&D project evaluation.

3.2 The synthetic evaluation of R&D projects

In order to acquire the synthetic evaluation of R&D projects, this study employs the fuzzy hierarchical analysis (FHA) (Buckley, 1985) to determine fuzzy weights of criteria and applies the fuzzy multi-criteria decision making (FMCDM) method for calculating the score of each R&D project so as to select the most potential and high value projects. According to Saaty (1980), pairwise comparisons have nine-level scale. Table 2 shows linguistic variables correspond to the rating scale.

Table 2. The rating scale.

Linguistic variable	Indefferent	Weakly important	Important	Very important	Extremely important	Intermediary values
Rating scale	1	3	5	7	9	2, 4, 6, 8

By using triangular fuzzy numbers, top managers or experts express the fuzzy relative importance of criterion i and criterion j and then produce the fuzzy positive reciprocal matrix. Through applying the normalization of geometric mean method, the

fuzzy weight of each criterion is obtained. According to Buckley (1985) and Saaty (1980), consistency index can be used to evaluate judgment consistency. In order to aggregate multiple experts' opinions, this study uses the fuzzy geometric mean method to obtain the average weight of each criterion. By employing weights of criteria and the performance evaluation of each criterion for a R&D project, the fuzzy synthetic evaluation of R&D projects can be obtained. In order to prioritize R&D projects, we use center of area (COA) method to obtain the nonfuzzy performance value.

3.3 Resource requirement of evaluation and allocation

In order to allocate limited resources, firstly, a general product development process in a specific industry is divided into several R&D activity groups. All product development projects must contain these R&D activity groups. This methodology based on activity groups to estimate the resource requirements of a product portfolio breaks the boundaries of R&D projects within a product portfolio, and allocate enterprise resources from a product portfolio viewpoint.

First, the same activity groups within a product portfolio are aggregated to form a classification. These same activity groups of the classification are arranged in sequence according to the product development sequence. As shown in Figure 3, there is a product portfolio which contains three projects, i.e., P1, P2 and P3. Each project contains three activity groups, i.e., A, B, C. These same activity groups within the product portfolio are aggregated to from classification 1, 2, 3 respectively. The result of the classification possesses the characteristic of dependence inside the classifications and independence between classifications.

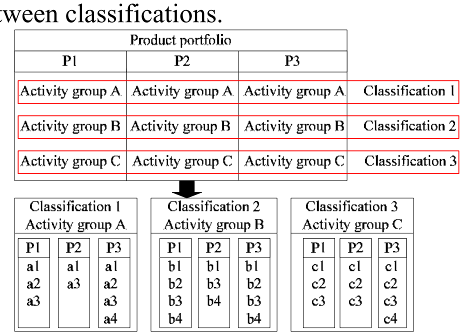

Figure 3. The classification of activity groups from a product portfolio perspective.

3.3.1 Requirement evaluation and allocation of product portfolio capital

Owing to the accumulation of R&D effects, subsequent R&D activities can utilize the previous R&D knowledge or experiences and invest less capital to achieve the activity targets. Hence, subsequent dependent activities inside a classification have completed partial work. Equation (2) displays the estimation equation of capital requirement.

$$\text{Capital requirement} = \sum_{g}\sum_{a} BAC_{a}^{g} + \sum_{g}\sum_{\substack{p \\ p\geq 2}}\sum_{a} AC_{p,\,a}^{g}\left(1 - S_{p,\,a}^{g}\right) \tag{2}$$

BAC_{a}^{g} : the cost of the specific activity (a) of the first R&D project within the specific classification (g).

$AC^{g}_{p,\,a}$: the cost of the specific activity (a) of the specific project (p).

$F^{g}_{i,a}$: the R&D result of the specific activity a of the specific project (i) increase a percentage of target achievement of the specific activity (a) of the specific project (p).

$S^{g}_{p,\,a}$: a percentage of target achievement of activity (a), project (p) and class (g).

3.3.2 Requirement evaluation and allocation of R&D facility

In order to shorten the product development time, oncoming R&D activities can employ the result of the most similar R&D activity within the classification. Hence, this study based on the core concept develops the approach. Equation (3) displays the formula for evaluating and allocating R&D facility resources.

$$FT_f = \sum_g \sum_a BAFT^{g}_{a,f} + \sum_g \sum_{p\geq 2} \sum_a AFT^{g,p}_{a,f} * \left(1 - MaxS^{g,p}_{a}\right) \tag{3}$$

FT_f : the expected use time of the specific facility (f) of the product portfolio.

$AFT^{g,p}_{a,f}$: the expected use time of the specific facility (f), activity (a), project (p).

$BAFT^{g}_{a,f}$: the expected use time of the specific facility (f), basic activity (a).

$S\left(A^{g,1}_{a}, A^{g,p}_{a}\right)$: the similarity degree.

3.3.3 Requirement evaluation and allocation of human resource

Owing to the accumulation of R&D knowledge and experiences gradually, work efficiency of R&D activities will be enhanced significantly. This study considers the impact to develop the approach for evaluating and allocating human resources. Equation (4) displays the formula for evaluating and allocating R&D facility resources.

$$MT_m = \sum_g \sum_a BAMT^{g}_{a,m} + \sum_g \sum_{p\geq 2} \sum_a AMT(1 - L^{g}_{p,a}) \tag{4}$$

MT_m : the expected work time of the specific human resource (m).

$BAMT^{g}_{a,m}$: Expected work time of the specific human resource (m) for executing the specific activity (a) of the first project within the specific classification (g).

$AMT^{g,p}_{a.m}$: Expected work time of the specific human resource (m) for executing the specific activity (a) of the specific project (p) within the specific classification (g).

3.4 Profit and risk analysis of product portfolio

In third phase, this study focuses on evaluating the risks and the profits of feasible product portfolios through employing design-for-performance concept of concurrent engineering.

3.4.1 The evaluation approach of product portfolio risk

The study proposes the risk evaluation approach of a product portfolio based on a hierarchical concept from the classification level to the activity-group level to calculate the success probability of a product portfolio. Equation (5) shows the formula of product portfolio risk. The classification risk is expressed as the intersection probability of R&D success events of activity groups within a classification. Owing to the dependent relationship among activity groups within a classification, subsequent R&D activity groups can employ the previous results of R&D activity groups. Hence, a classification risk can be attained by using a conditional probability as shown in Equation (6).

$$\text{Portfolio Risk} = P(C_1 \cap C_2 \cap \cdots \cap C_m) = P(C_1)\, P(C_2) \cdots P(C_m) = \prod_{i=1}^{m} P(C_i) \quad (5)$$

$$\begin{aligned} P(C_i) &= P(AG_{i,1} \cap AG_{i,2} \cap \cdots \cap AG_{i,n}) \\ &= P(AG_{i,1})\, P(AG_{i,2} \mid AG_{i,1}) \cdots P(AG_{i,n} \mid AG_{i,1} \cap AG_{i,2} \cap \cdots \cap AG_{i,n-1}) \end{aligned} \quad (6)$$

Ci : the specific classification (i), and $AG_{i,j}$ is the specific activity group (j) within the specific classification (i).

3.4.2 The evaluation approach of product portfolio profit

This study proposes the evaluation approach of a product portfolio profit as shown in Equation (7). In order to objectively estimate, the approach considers the substitute effect among products within a product portfolio. Hence, this paper divides the products of a portfolio into two categories. The products of the first category have no substitute effects each other, but the products of the second category have the substitute effect.

$$TNER = \sum_i ER_i + \sum_i SER_i \quad \text{where } SER_i = \sum_{t \geq 1} \frac{CF_t^i}{(1+K)^t}\left(1 - S_i^p\right) \text{ and } ER_i = \sum_{t \geq 1} \frac{CF_t^i}{(1+K)^t} \quad (7)$$

ER_i : the revenue of the specific product (i) within the first category.

SER_i : the revenue of the specific product (i) within the second category.

CF_t^i : the expected cash flow of the product (i) at period t.

S_i^p : the substituted intensity of the specific product (i) within the specific portfolio (p).

4. Case Study

This paper chooses the mobile phones of new product projects as a case to demonstrate the systematic analysis of product portfolio strategy.

4.1 Evaluation and selection of new mobile-phone development projects

In the third phase, three top managers participate in evaluation and selection of mobile-phone development projects. Table 3 displays the criteria weights of the technology dimension.

Table 3. The fuzzy average weights of criteria

Dimension	Criterion	Triangular fuzzy numbers		
Technology	Design for environment	0.0095	0.0653	0.6022
	Availability of critical parts	0.0095	0.1036	0.6804
	Design for manufacturability	0.0071	0.0653	0.4935

In this case study, there are five new product development projects, i.e., the multimedia mobile phone, the camera mobile phone, the smart mobile phone, the MP3 mobile phone, and the Wi-Fi mobile phone. Table 4 shows the future profits and the NPV of the camera mobile phone given by one of three top managers. According to the profit of a company and the mobile-phone industry conditions, top managers decide the profit intervals (defined in triangular fuzzy models) with respect to linguistic variables. Using the model, we identify the linguistic variable value is “good”.

Table 4. The future profits and the NPV of the camera mobile phone.

NPV=10083.9							
Period t	0	1	2	3	4	5	6
Cash flow at period t	-2300	2000	3200	3600	3200	2600	1600
Period t	7	8	9	10	11	12	
Cash flow at period t	1000	0	0	0	0	0	

(Unit of cash flow: ten thousands)

This study divides a new mobile-phone development process into four activity groups, i.e., industrial design, electronic design, mechanism design, system integration. Table 5 displays that the manager gives the success probability of each activity group for the camera mobile-phone development project. We also obtain the linguistic variable values and their corresponding triangular fuzzy numbers using the approach described in Section 3.1.

Table 5. The risk of activity groups and camera mobile-phone project

The risk of the camera mobile phone project						0.901	
Industrial design	0.999	Electronic design	0.975	Mechanism design	0.98	System integration	0.96

4.2 The evaluation and allocation of resource requirements

Due to the limited resources, feasible product portfolio can provide top managers to choose the most appropriate product portfolio strategy. The approach for evaluating resource requirements of product portfolios is based on R&D activities. In order to further analyze, this paper drill down the four activity groups of a mobile-phone R&D development process. By using the approach proposed in this paper, we can obtain the resource requirements of product portfolios. We list resource requirements of feasible product portfolio ‘D’as shown in Table 6.

Table 6. Resource requirements of the product portfolios

Products: {Camera mobile phone, MP3 mobile phone, smart mobile phone}				
Capital	R&D facility (Unit: hour)		Human resource (Unit: hour)	
1803	Computer aid design software	6220	Industrial design engineer	254
	Mold flow analysis application	72	Mechanism engineer	7760
	Abrasion tester	8	Quality engineer	73
	Pendulum impact tester	15	Electronics engineer	8200
	Adherence tester	8	Radio frequency engineer	4013
	Circuit design software	6950	Software engineer	8900
	System development software	4872	Testing engineer	1690
	Optics lab	1240	Optical engineer	1350
	Radio frequency lab	3302		

4.3 The analysis of profit and risk of product portfolios

Table 7 displays the risks and profits of the product portfolios. Owing to little differences among the risks of product portfolios, the most appropriate product portfolio strategy chooses the high profit of product portfolio 'E'.

Table 7. The risks and the profits of product portfolios

Product portfolio (Products)	Profit	Risk
B (Camera mobile phone, multimedia mobile phone, MP3 mobile phone)	31226	0.863
C (Camera mobile phone, multimedia mobile phone, smart mobile phone)	49145	0.834
D (Camera mobile phone, MP3 mobile phone, smart mobile phone)	40735	0.853
E (MP3 mobile phone, multimedia mobile phone, smart mobile phone)	54627	0.794

5. Conclusion

Following the principle of concurrent engineering, this research develop and demonstrate a systematic analysis process for PPM, which simultaneously considers internal and external factors, such as potential profits, risks, technical capability, etc., during the early design stage. In order to achieve the research objective, this study also depicts a novel methodology for evaluating the resource requirements and analyzing the feasible product portfolios. This methodology breaks the barriers of projects within a product portfolio and employs the activity-group concept to analyze the resource requirements and to evaluate the profit/risk of the plausible product portfolios. In order to demonstrate the merit of the methodology, we have conducted an in-depth case study in the mobile-phone PPM. The result has been verified by the top manager of a major mobile phone company to be extremely valuable toward the product portfolio strategic decision making using a scientific methodology.

6. Acknowledgement

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Business development process assisted by QFD

Marcelo Farhat de ARAUJO [a, b, 1] , Luís Gonzaga TRABASSO [a, 2]
[a] *Instituto Tecnológico de Aeronáutica (ITA)*
[b] *Mectron EIC Ltda*

Abstract. Start-up companies during their business development process could face a decision dilemma that makes them wonder if their resources should be applied to support the present operation or to promote the required business improvements. An approach using the theory of inventive problem solving (TRIZ) is presented to overcome this impasse and one of the possible identified solutions is described, where the requirements of a national quality award e.g. the Baldrige National Quality Program (BNQP) are used to reduce the effects of the identified dilemma. Finally, a case study is exposed where the quality function deployment (QFD) is proposed to assist the early planning phases of a business development process.

Keywords. Business development; Quality Function Deployment (QFD); TRIZ; National Quality Award.

Introduction

The usual business evolution process isn't a straight line to a rewarding future; frequently, it would lead companies to face arduous obstacles and severe crisis. However, this deceptively picture could be managed and transformed into opportunities of development and new strong market positions should be implemented by the company effort translated by learning, innovation and structural changes. Constant cycles of crisis and amendments allied with the intrinsic uncertainty convert the conduction of this process into a tough task, mostly when the process is guided essentially by the reaction against the changes on the market scenarios, driving the company toward an undetermined direction.

As an answer to this inherent loss of focus, authors e.g. Porter [1], Lobato [2] and Shapiro [3], endorse the adoption of a competitive strategic management process, with a systematic approach of continuous improvement. Even though the competitive strategic management is identified as a worthy process, the costs experienced during its implementation and execution, are significant and may not be supported by start-up companies. This paper proposes an alternative procedure to reduce the effects of this dilemma stated as follows: should the company resources be applied to maintain the operational and prospecting tasks that support the current status or to the long term plans that would promote the required business improvements that would lead it to a stronger market position?

[1] Author e-mail: m.f.araujo@terra.com.br
[2] Author e-mail: gonzaga@ita.br

1. Resources Wear Out Dilemma

Resources scarcity does not occur only with start-up companies; however the consequences of the inadequate resource application tend to be more severe for this type of enterprises, in which a fault could lead to the risk of exhausting all their savings [4]. It is not unusual that a potential crisis is identified and a company structural improvement should be implemented to overcome it: consequently, the resources wear out dilemma would emerge simultaneously.

This deadlock shows up when the company has to choose if its resources should be invested on the prospecting and production tasks, that support the present operation or on the plans that would be able to guarantee strong market positions in the future. Apparently, a deadlock is seen as a no-escape-trap, although many inventions have arisen from contradictions identified as unfeasible for many years. Altshuller [5] in his theory of inventive problem solving (TRIZ) presents many examples of creative and simple solutions that transpose the initial system contradiction with a lot of benefits.

TRIZ application on management processes has been studied by several authors [6], [7], [8], [9]; who have presented practical examples and proposed methods to deal with systems based essentially on information. In all cases an analogy should be proposed in order to associate the actual system properties with the physical properties shown on the TRIZ contradiction matrix.

The dilemma presented herein has been identified as: to perform as many tasks as possible (operational and improvement tasks) against the company available resources. The TRIZ analogy found was: capacity or productivity against loss of system energy.

Analyzing the contradiction matrix [5] the following inventive principles have been identified (naturally, one can see they are related to tangible product design):

- Replace mechanical system.
- Transformation properties.
- Prior action.
- Pneumatic, hydraulic construction[3].

The first inventive principle, replace mechanical system, would induct solutions that increase the automation level of tasks, even in the production process or on management activities and consequently improving the efficiency. However the investments required could exceed the company assets.

The transformation properties principle would lead to a promising system rearrangement, where a pool of organizations sharing their resources could elucidate the problem. However, this solution is very complex; due to a significant number of compatible companies facing the same kind of troubles should be identified.

The last principle, prior action, was recognized as the utilization of previous efforts made by other organizations toward their management excellence. A wide range of business reference models are available at low cost. These models encompass good practices adopted by successful companies and structured requirements that could lead the company through its improvement changes. The adoption of a reference model could save worthy resources [10] due to:

- A direction is clearly determined lot of on the run discussions are eliminated;
- The model should be used as a road map, saving time of planning;
- Success cases are available for further analysis.

[3] pneumatic, hydraulic construction was considered not applicable due to the nature of system under analysis

2. Requirements for Business Development

As soon as the general idea of adoption of a reference model is a consensus, the next decision would be on the choice among the several available. A literature review shows many different reference models, with diverse format, intended goal and complexity. The observed variety allied with the individual company's characteristics; make difficult the evaluation of the model that best fits the enterprise needs. From the set of reference models available, those listed were selected and analyzed (see Table 1):

- Standardized quality assurance systems, e.g. ISO9001:2000 [11], AS9100 [12] and ISO/TS 16949 [13].
- Specific business process models, e.g. PACE Product and cycle-time excellence model [14], SCOR Supply chain excellence [15] CMMI Capability Maturity Model Integration [16].
- National quality award requirements, e.g. Baldrige National Quality Program (BNQP) [17], EFQM Excellence Award [18], Brazilian National Quality Award (PNQ) [19].

Table 1. Main features of the analyzed reference models.

Reference Model	Requirements	Purpose	Documentation and training	Amplitude of effect	Revision frequency	Prior action affinity
Standardized quality assurance systems	Clearly defined	Fulfill customer's and regulatory requirements.	Standards, training courses and consulting	Value creating processes supports.	On a regular basis	Low
Specific business process models	Clearly defined	Achieve excellence in the specific process	Books, manuals, training courses and consulting	A specific process and its interfaces	Frequently	High
National quality awards	Clearly defined	Achieve excellence in business management	Manuals, cases for study, training courses and consulting	All company[4]	Annually	High
Competitive strategic management[5]	Defined on the run	Best performance when facing threats.	Books, consulting	All company	Not assessed	None

Although all the reference models presented could bring benefits to their users, a carefully analysis of the differences shown on Table 1 can help the choice of the best one that would suite the company needs and reveal characteristics that facilitate or make difficult their implementation.

Resuming the analysis of the initial dilemma detailed in Section 1, the reference model chosen was a national quality awards requirement due to:

- The requirements are clearly defined and determined based on best practices observed on successful organizations.
- A quest for excellence would be promoted since the early evolution phases. It is the doing right at the first time motto.

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[4] National quality awards could be a single item of the strategic planning of huge companies.

[5] Although the competitive strategic management is not available as a reference model format, it was analyzed and presented in Table 1 in order to compare this more complex system to the others.

- All business processes would be involved during the quest for excellence.
- There is a lot of reference material available e.g. manuals, cases for study and training courses at low cost.
- Requirements are annually reviewed and updated.
- The implementation plan could be tailored to fit the actual needs of the organization, according to its development stage and budget.

3. The Project for Business Development

The reference model choice is only the first step of the project for business development. A great amount of labor hours should be invested in planning, executing and controlling the changes that have to be performed, so the efficiency and accuracy of the subsequently tasks are very important to guarantee the minimal resources waste.

For this reason, the use of methods that assists the project planning phase such as the Project Management Body of Knowledge (PMBOK) [20] and the Critical Chain [21], among others, is recommended. Without any contradiction with these methods, the authors suggest a procedure to assist the early planning and project definition phases of the company's quest of excellence using the Quality Function Deployment (QFD) [22]. In doing so, the main advantage obtained is to group all the company efforts in a unique map that shows how the requirements are accomplished and gives an overall view of the established action plans.

Additionally, QFD is a native tool within the product development environment whose purpose is to drive the design and manufacturing tasks to meet the customer's needs and requirements. Clearly, some adjustments should be implemented to bring QFD to the business development environment. Essentially the alterations were performed in the QFD matrices inputs and outputs, as shown in Table 2, and on the requirements importance weights that were replaced by the quality award requirement point values i.e. the BNPQ [17] requirement point values.

Table 2. QFD matrices comparison between product and business development.

QFD Matrix	Product development		Business development	
	Input	Output	Input	Output
1	Customers needs	System requirements	Stakeholders needs	Model requirements
2	System requirements	Parts characteristics	Model requirements	Action plans
3	Parts characteristics	Production processes	Action plans	Business processes
4	Production processes	Manufacturing operations	Business processes	Critical tasks

Another advantage gathered from the choice of a national quality award as the reference model to be pursuit is observed by the fact that the expected result from the first QFD matrix has already been achieved when the Quality Award requirement was determined.

The analysis of the process that creates the BNPQ criteria revealed that surveys were carried out in high-performance companies with the purpose of determining the characteristics that make them successful, in order to reveal the concepts that represent the expectations of all organization's stakeholders i.e. the inputs of the first QFD matrix (see Table 2). The BNPQ criteria and weights were built upon these concepts i.e. the output of the first QFD matrix.

So, the company's business development project could initiate from the second QFD matrix where the quality award criteria are deployed into actions plans, that represents the company actual planed effort to accomplish the established requirements. Figure 1 depicts the second QFD matrix where the BNQP criteria are deployed into a set of action plans. The relationship intensity criterion adopted is shown in Table 3.

Table 3. Relationship criterion for all QFD matrices.

Relationship Intensity	Value (R)	Symbol
Strong	9	●
Average	3	⦿
Weak	1	○
None	0	

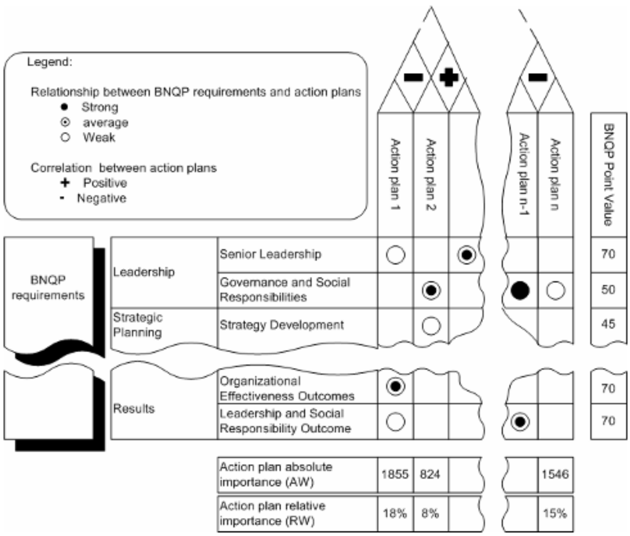

Figure 1. BNQP requirement deployment: 2nd QFD matrix

The BNPQ weighting values and relationship score between requirements and action plans is used to determine the relative importance among the action plans (see Eq. 1 and 2). This result drives the company to focus the efforts to the activities that have the higher value scores. Consequently, a prioritized list of action plans is created.

$$AW_j = \sum_{i=1}^{p} \left(PV_i x R_{ij} \right) \tag{1}$$

where AW = action plan absolute importance; PV = BNQP pint value; Rij = relationship value between the requirement and the action plan; p = number of requirements; i = requirement index; j = action plan index.

$$RW_j = \frac{AW_j x 100\%}{\sum_{j=1}^{n} AW_j} \tag{2}$$

where RW = action plan relative importance; n = number of action plans; and j = action plan index.

Recursively, in the 3rd QFD matrix the most important action plans could be deployed into the company's business processes and these processes into its critical tasks, yielding the 4th QFD matrix, in order to display how the company's operation would support the business development project. However, the deployment level should be individually analyzed for each project and could vary according the company complexity. Process importance factors could be assessed on the 3rd QFD matrix, with few adjustments on equations 1 and 2. The setting up of threshold level used to filter items from one QFD matrix to another is out of the scope of this paper; however, this could be found in Loureiro [23].

The correlation among the action plans offers new opportunities to explore systems contradictions i.e. each action plan pair that presents a negative correlation e.g. action plans 1 and 2 (see Fig. 1), should be analyzed with the help of the TRIZ.

4. Case Study

The case study here presented has been running since 2005 with the purpose of validating the procedure previously detailed. The case study organization is a kindergarten to elementary education school, based in São José dos Campos, Brazil, operating since 1983, currently with 85 employees and about 500 students. However; its quest for excellence was initiated two years before, when the Brazilian National Quality Award (PNQ) [19] was selected as a guideline for its business development.

In the first two years many actions were started, which, however lacked focus and control. For this reason, the method proposed herein was seen as a valuable tool to help the planning phase. From then up to now, the following activities have been conducted:

- Identification of initiatives related to the quest for excellence process.
- Definition of the set of action plans to encompass all the initiated tasks.
- Deployment of the quality award requirements into action plans.
- Deployment of the action plans into the company's business processes.

The first step was consisted of an extensively internal survey to find out the actions, programs and efforts performed by the organization that could contribute to any PNQ requirement. Amazingly, it has been found 72 different efforts with several levels of control, implementation progress and complexity. This mess of purposes and goals had so far toughened the control and the understanding of the entire project scope. Although, all of these actions have been identified, many of them had similar purposes and were guided by the same person. Then, they were grouped into a set of 39 actions, even though the new clusters were not able to solve completely the problem initially identified and a second approach was carried out and a set of action plans was determined with the aid of a criterion stated by Verzuh [24]. According to that, for every action plan should be defined:

- Clear goals and outputs that lead to a controlled scope;
- One and only one coordinator;
- A deadline and a list of measures of effectiveness correlated with the outputs;
- An allocated team.

After applying this approach, a set of 12 action plans was proposed and its relationships with the PNQ requirements were determined. Noticeably, some requirements were not completely fulfilled, which illustrates a lack of some planned actions. The QFD arrangement for these relationships, associated with the weighs of

the requirements led to the assessment of the relative importance among the action plans, what, by its turn, was used to define priorities and assure that the resources are spent in the most important actions. Next, the action plans were deployed into the company's business processes (Figure 2) which also shows the actual involvement of the company's functional structure.

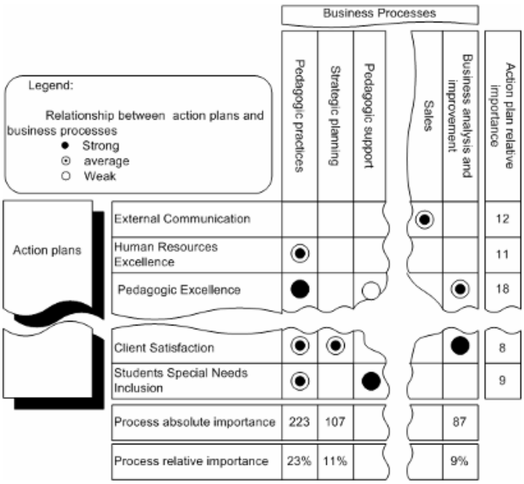

Figure 2. Case study: Action plans deployment.

Even tough the case study is still running; the following preliminary results have already been identified:

- Reduction of the necessary project controlling effort;
- Team tasks are focused toward the direction of the long term goals defined and supported by the selected reference model;
- Main business processes are easily identified;
- Task priority is clearly displayed by the QFD matrices;

In order to conclude the case study it is necessary to carry out the following tasks:

- Additional action plans or changes in scope should be implemented.
- It should be analyzed if the business processes deployment should be applied.
- At least one feedback cycle should be executed to improve the proposed procedure with the experience gathered during the implementation process.

5. Conclusions

Although the competitive strategic planning process is highly recommended by several authors e.g. Porter [1], Lobato [2] and Shapiro [3], to guide the business development project, start-up companies could not afford the cost involved.

On the other hand, a continuous business evolution is compulsory to keep the company focused in the marketing requirements. Therefore low cost solutions should be pursuit. One of the possible solutions is the use of available reference models to conduct the company on the way of a desired and planned future. This paper has proposed the use of the TRIZ to conduct the selection of a method that best fit a given business scenario. Also, the authors have suggested the usage of QFD as a tool to assist the business development process planning phase of a company. When applied to a

case study company, it leads to a considerable simplification of business scenario where 72 distinct actions were translated into 12 action plans. Furthermore, QFD has helped rank the action plans, optimizing the resources allocation as a consequence.

The project scope completeness could be inferred by analyzing the relationship between the requirements and the action plans, whereas this investigation is based on the subjective judgment if a requirement is poorly supported by the set of proposed action plans. Additional studies should be performed to carry out this weakness and turn the analysis more objective.

Other important observation, related to the use of TRIZ on non-technical systems, was the fact that analogies can make possible the use of the contradiction matrix and the isolation of inventive principles that produce numerous potential creative solutions.

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Integrated CE tools for postponed aerospace product and process decisions

Cássio Dias GONÇALVES [a,1], Luís Gonzaga TRABASSO [a,2], Geilson LOUREIRO [b,3]
[a] *Aeronautics Brazilian Institute of Technology (ITA)*
[b] *Integration and Testing Laboratory (LIT) Brazilian Institute for Space Research (INPE)*

Abstract. This paper aims to develop, demonstrate and justify a quantitative method that identifies the best kind and optimal level of postponement that should be adopted in an Aerospace Company to promote production cost reduction, improving customer service, offering short times of delivery and increasing the overall program profit. This method also intends to determine the best time to make the main decisions during the product development project.

Key words. Postponement; Concurrent Engineering; Competitiveness.

Introduction

Nowadays companies must adopt strategies to address new global market needs. This work deals specifically with the aerospace market, where the competition is very high and the customers want customized products, short delivery times and low price [1]. These combined with high uncertainty scenario makes the demand forecast a very hard task.

If a company makes a inaccurate demand forecast, this often will generate changes in the schedule of customer orders, and it will cause discontinuities in the assembly line to reconfigure aircrafts, affecting the planning capacity [2] and increasing production costs. On the other hand, if the company offers a high level of product customization, the cost with reconfigurations increases.

Therefore, to keep itself competitive at the global market, the company must avoid the occurrence of aircraft's reconfigurations, adopting a strategy to make its customization process more flexible, postponing the product configuration to as late as possible in the production phase [3]. This reduces production costs, improves customer service as delivery time is shortened and increases the overall program profit.

[1] Corresponding Author: Cássio Dias Gonçalves, Av. Independência, 531, apto 112A, CEP.: 12031-000, Taubaté, São Paulo, Brazil; E-mail: cdgoncal@yahoo.com.br.
[2] Corresponding Author: Luís Gonzaga Trabasso, ITA, Praça Marechal Eduardo Gomes, 50, Vila das Acácias
CEP 12228-900, São José dos Campos, São Paulo, Brazil; E-mail: gonzaga@ita.br.
[3] Corresponding Author: Geilson Loureiro, INPE, Av. dos Astronautas 1758 Jd. da Granja CEP.: 12227-010, São José dos Campos, São Paulo, Brazil; E-mail: geilson@lit.inpe.br.

This strategy is named postponement: an operational concept that consists of delaying the product configuration until the actual customer demand is known [4].

Rarely, authors mention the relationship between postponement and concurrent engineering; however this is an important requirement for the implementation of this strategy. The strategy addresses the following issues:

- integration among different technical areas such as Product Engineering, Process Engineering, Logistics and Sales Department;
- main factors that affect the customer needs [5]: 1) the aircraft's operational cost, 2) the number of optional items offered to the customer and 3) the aircraft's delivery time;
- some factors affecting costs: 1) inventory levels may change [6][7], 2) high value added items may be installed earlier or 3) design solutions may affect the product cost.

Considering these characteristics, a company may create many alternatives of product design and manufacturing processes to implement postponement [8], for example: applying design modularization [9]; constraining the number of optional items [10]; employing buffers for the component bottlenecks or reorganizing manufacturing processes to install the parts that configure the product as late as possible.

The work described herein has identified some concurrent engineering tools that may help to make decisions at the right time and choose the best product alternative. These are: Design to Cost (DTC), Quality Function Deployment (QFD), Decision Trees [11][12], Multi-criteria Systems, Design Structure Matrix (DSM) and Critical Path Method (CPM). This paper proposes a quantitative postponement method that makes an adapted and systematic use of those tools, provides an example of application and discusses the effect of such method on cost reduction and customer satisfaction.

1. Method

Figure 1 provides an overview of the method proposed and demonstrated in this paper. This section details each box in Figure 1.

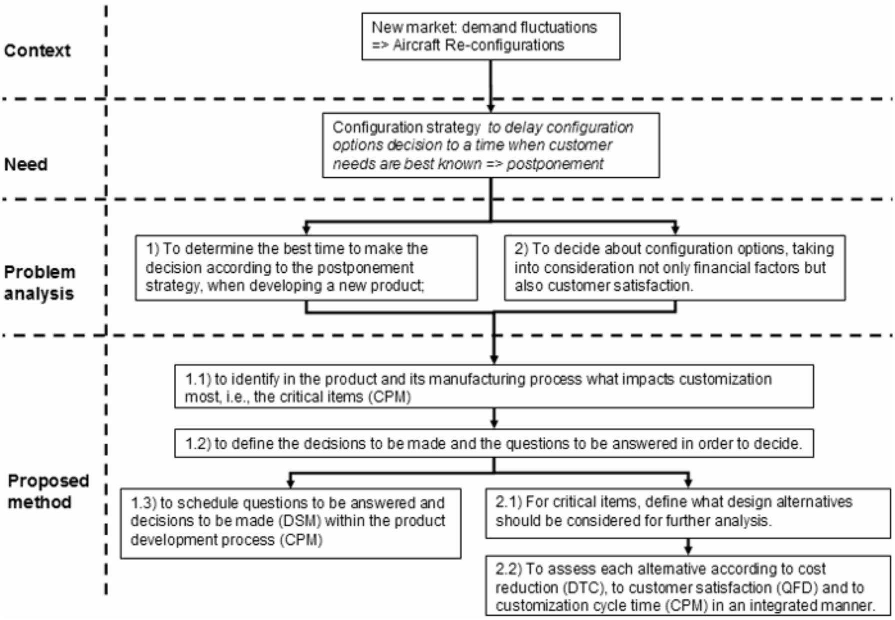


Figure 1. An overview of the proposed method

The problem to be tackled can be divided into two parts. The first is related to the accomplishment of an important milestone in an aircraft development process: to use or not the postponement strategy to produce an aircraft. The second part consists in supporting the decision made, through the choice of the best design alternative, which presents lower cost, while keeping focus on customer needs. The present work focuses on the second part of the problem (see Box 2 of Figure 1).

The CPM will be used to develop the precedence network of the aircraft manufacturing and assembly processes [13]. Then it is possible to identify the most critical items that contribute to increase the customization cycle time (as shown in Box 1.1 of Figure 1). Through this precedence network, the level of postponement (as depicted in Figure 2) is calculated based on:

$$C_{custom} = C_{cm} + C_{ca} \qquad \text{Eq. 1}$$

where,
C_{custom} = aircraft customization cycle time [days]
C_{cm} = customization cycle time for manufacturing [days]
C_{ca} = customization cycle time for assembly [days]

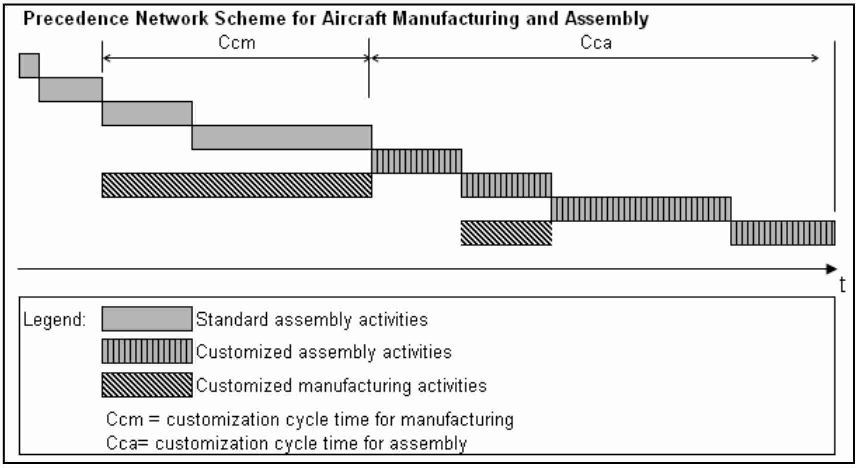


Figure 2. Aircraft's customization cycle time.

Once the actual customization cycle time is identified, some questions and decisions are formulated about the design and manufacturing of the critical items to promote this cycle time reduction (see Box 1.2 of Figure 1). Depending on answers for these questions and decisions, different aircraft and its manufacturing process design alternatives will be created (see Box 2.1 of Figure 1).

The QFD and DTC tools will help to determine the best aircraft design and manufacturing alternative according to cost constraints and customer needs (see Box 2.2 of Figure 1). Where, through QFD, the customer needs will be related with the company's engineering and manufacturing requirements. The QFD tool also will weight the relationship between these requirements and the aircraft's parts and manufacturing processes. The DTC technique will be used to compare the target costs with the estimated costs, pointing which aircraft part or process must be redesigned to attend the target cost.

Total Probability Theorem [11] helps to define the optional kits for the aircraft.

To solve the first part of the problem (Box 1 of Figure 1), it is needed to consider three kinds of elements in a decision making process: milestones, decisions and questions, and they relate to each other as following [14]:

- The milestones accomplishments depend on the decisions made;
- Decisions depend on the answer of some questions;
- Also, milestones may depend on other milestones, decisions may depend on other decisions and questions may affect each other.

The numerical DSM activity-based tool can be used to create the relationships among these elements and rank them according to a priority criterion. In this work, a DSM adaptation is required to define each activity time length, instead of priority relationships [15]. The CPM was selected to determine the best time each element takes place in a new aircraft development project [16]. CPM can be used because the statistical variance of the activity durations is insignificant [17]. The Primavera Project Planner (P3) has been used to implement CPM [18]. As shown in Box 1.3 of Figure 1, the Numerical-DSM is used and its results are input to P3 to generate the project activities programming [19]. After this precedence network is calculated, it is related

with a product development plan to determine the ideal schedule to answer each question, to make the decisions and to accomplish the milestones, without affecting the program end date.

2. Case Study

Applying CPM to the aircraft manufacturing and assembly process, allows the definition of the most critical aircraft components, which increases the value of C_{custom} [20]. They are: main hardness, furnishings (interiors) and electronics equipments (such as avionics, entertainment options) – see Table 1. After the identification of these items, some questions and decisions are formulated about how the design and manufacturing of these components can contribute to reduce C_{custom}. The answers for these questions and the decisions made define the level of postponement is used to produce the aircraft. Table 1 lists those questions and decisions.

Table 1. Questions and decisions list.

Code	Description	Technical Area
D1	**Hardness: Standard; customized; standard in cockpit and customized in fuselage.**	
Q1	Is it technically possible? (Weight, fabrication, assembly)	System Eng, Weight, Manufacturing
Q2	Is it profitable? (Trade-off)	Process Eng and Supply
Q3	Do the customization cycle time reduce?	Process Engineering
Q4	Is the customer needs affected? (Positive, negative, how much?)	Market and Sales Department
Q5	Is the fabrication lead time so far?	Process Eng and Supply
D2	**Interiors: Standard; customized; standard cockpit and customized PAX cabin.**	
Q1	Is it technically possible? (Weight, fabrication, assembly)	System Eng, Weight, Manufacturing
Q2	Is it profitable? (Trade-off)	Process Eng and Supply
Q3	Do the customization cycle time reduce?	Process Engineering
Q4	Is the customer needs affected? (Positive, negative, how much?)	Market and Sales Department
Q5	Is the fabrication lead time so far?	Process Eng and Supply
D3	**Number of optional items: constrained or not constrained.**	
Q6	How many optional items?	System Eng and Market Dep.
Q7	Which optional items will be offered?	System Eng and Market Dep.
Q8	How to determine? (Total Probability Theorem)	Process Engineering and Market
Q9	Is the customer needs affected? (Positive, negative, how much?)	Market Department
Q10	Will the kits be created?	Process Engineering and Market
D4	**Production buffers: to use or not?**	
Q5	Is the fabrication lead time so far?	Process Engineering
Q11	Is it profitable? (Trade-off)	Process Engineering

Combining the options of decisions (listed in Table 1), a lot of design alternatives could be generated for the product and its manufacturing process. This study evaluates only two design alternatives. Basically, the set of decisions made for Alternative 1 does not contribute to postponement usage. On the other hand, the set of decisions made for Alternative 2 enable the postponement utilization to produce an aircraft. The alternatives characteristics are shown in Table 2.

Table 2. Characteristics of product and process design alternatives.

ALTERNATIVE 1	ALTERNATIVE 2
Customized hardness	Standard hardness in cockpit and installed during Pre-equipage phase and customized in the fuselage installed during the Final Assembly Phase
Structural customization during the Structural Complementation Phase (best time technically)	Standard fuselage structure

Optional items limits unconstrained	Offered 4 kits of optional items.
No optional items stock.	Optional items stocked
Customized interior and installed during Final Assembly Phase.	Stock for 4 kinds of hardness
No interior items stock.	Standard interior in cockpit and customized in PAX cabin (less optional items => reduced stock)
	Pre-equipage of forward fuselage (to facilitate access to cockpit and to reduce customization cycle time)

The CPM was used also to determine the customization cycle time. According to the precedence network of aircraft manufacturing, related to Alternative 1 and Eq. 1, the value of $C_{custom\ 1}$ is:

$$C_{cm} = C_{cm\ 1}\ \text{[days]}$$

$$C_{ca} = C_{ca\ 1}\ \text{[days]}$$

$$C_{custom\ 1} = (C_{cm\ 1} + C_{ca\ 1})$$

Alternative 1 does not adopt any kind of production buffers to the optional items, then the manufacturing lead times are included in the customization cycle time, significantly increasing it.

According to the precedence network of aircraft manufacturing, related to Alternative 2 and Eq.(1), the value of $C_{custom\ 2}$ is:

$$C_{cm\ 2} = 0\ \text{[day]}$$

$$C_{ca\ 2} = (C_{ca\ 1}).0{,}623\ \text{[days]}$$

$$C_{custom\ 2} = C_{cm\ 2} + C_{ca\ 2} = 0 + (C_{ca\ 1}).0{,}623$$

$$C_{custom\ 2} = 0{,}623.(C_{ca\ 1})\ \text{[days]}$$

Alternative 2 proposes to offer optional kits to customer, as in the automotive industry. It was applied the Total Probability Theorem to determine the number of kits and its compositions [11].

Table 3. Unconditional probabilities of the optional items

Optional Items	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13
Probability of a customer to choose the item (%)	85	11	5	12	0	50	11	5	6	10	8	79	13

Combining the optional items in assembly kits with three items, it was possible to identify the 4 combinations most demanded by the global market: B1B6B12, B1B12B13, B6B12B13 and B1B6B13. Due to the creation of 4 kinds of kits, it is necessary to keep 4 kinds of hardness in stock.

The best alternative, considering the program cost constraints and customer needs, will be identified through techniques such as QFD and DTC.

For each alternative will be generated three matrices in the following order: First QFD Matrix, Second QFD Matrix and DTC Matrix. These matrices are interrelated as can be observed in Figure 3: the first QFD matrix relates the aircraft design and manufacturing requirements (System Requirements) with the Customer Needs; the second QFD matrix, the design and manufacturing characteristics of the critical components (Parts Characteristics), with the System Requirements. Finally, the DTC matrix helps to make the System Requirements cost estimation from Parts Characteristics. Then, this estimated cost is compared with the program target cost, weighted according to how customer values their needs accomplishments.

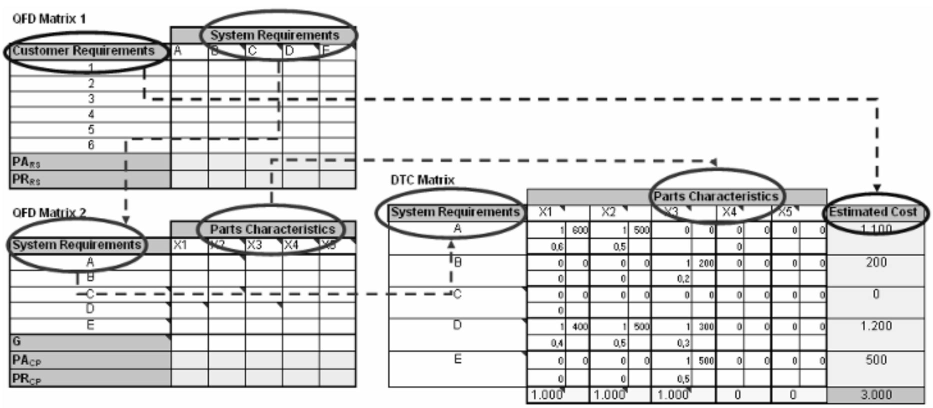


Figure 3. QFD and DTC matrices scheme.

Follow the set of matrices for Alternative 1 (Table 4, Table 5 and Table 6) and Alternative 2 (Table 7, Table 8 and Table 9).

Table 4. QFD Matrix 1 for Alternative 1.

QFD Matrix 1	System Requirements									
Customer Requirements	Light weight aircraft	Wide scale production	Flexible assembly line	Low n° of components	Standard assemblies	Importance	Improvement rate	High sales points	PA$_{RC}$	PR$_{RC}$
Low operational cost	9					4	1,1	1	4,40	18,64%
Short delivery times		9	9		3	5	1,7	1	8,50	36,02%
High offer of optional items	3	1	3	1	1	3	1,1	1	3,30	13,98%
Simple maintenance				3		2	1,2	0,5	1,20	5,08%
Simple inspection	1	1		9	1	3	1,2	0,5	1,80	7,63%
Quality	1	1	1	3	9	4	1,1	1	4,40	18,64%
PA$_{RS}$	2,36	3,64	3,85	1,54	2,97					
PR$_{RS}$	16,43%	25,37%	26,78%	10,71%	20,71%					

Table 5. QFD Matrix 2 for Alternative 1.

QFD Matrix 2	Parts Characteristics						
System Requirements	Custom. Hardness	Custom structure at Structural Completion	Custom interior at Final Assy	No interior stock	No optional equip. stock	PA_{SR}	PR_{SR}
Light weight aircraft	9	3				2,36	16,43%
Wide scale production			1			3,64	25,37%
Flexible assembly line		1				3,85	26,78%
Low n° of components	3	1	1			1,54	10,71%
Standard assemblies		1				2,97	20,71%
G	5	3	4	4	4		
PA_{CP}	9,00	3,22	1,44	0,00	0,00		
PR_{CP}	65,85%	23,59%	10,56%	0,00%	0,00%		

Table 6. DTC Matrix for Alternative 1.

DTC Matrix	Parts Characteristics												
System Requirements	Custom. Hardness		Custom structure at Structural Completion		Custom interior at Final Assy		No interior stock		No optional equip. stock		Estimated Cost	PR_{SR}	SR Target Cost
Light weight aircraft	1	206270,3	1	968504,63	0	0	0	0	0	0	1.174.775	16,43%	496.124
	0,6		0,5				0						
Wide scale production	0	0	0	0	1	271393	0	0	0	0	271.393	25,37%	766.009
	0		0		0,2								
Flexible assembly line	0	0	0	0	0	0	0	0	0	0	0	26,78%	808.763
	0												
Low n° of components	1	137513,5	1	968504,63	1	407089	0	0	0	0	1.513.107	10,71%	323.327
	0,4		0,5		0,3								
Standard assemblies	0	0	0	0	1	678482	0	0	0	0	678.482	20,71%	625.277
	0		0		0,5								
	343.784		1.937.009		1.356.963		0		0		3.637.756		3.019.500

Table 7. QFD Matrix 1 for Alternative 2.

QFD Matrix 1	System Requirements									
Customer Requirements	Light weight aircraft	Wide scale production	Flexible assembly line	Low n° of components	Standard assemblies	Importance	Improvement rate	High sales points	PA_{CR}	PR_{CR}
Low operational cost	9					4	1,1	1	4,40	20,66%
Short delivery times		9	9		3	5	1,7	1	8,50	39,91%
High offer of optional items	3	1	3	1	1	3	1,1	1	3,30	15,49%
Simple maintenance				3		1	1,2	0,5	0,60	2,82%
Simple inspection	1	1		9	1	2	1,2	0,5	1,20	5,63%
Quality	1	1	1	3	9	3	1,1	1	3,30	15,49%
PA_{SR}	2,54	3,96	4,21	1,21	2,80					
PR_{SR}	17,22%	26,89%	28,61%	8,23%	19,04%					

Table 8. QFD Matrix 2 for Alternative 2.

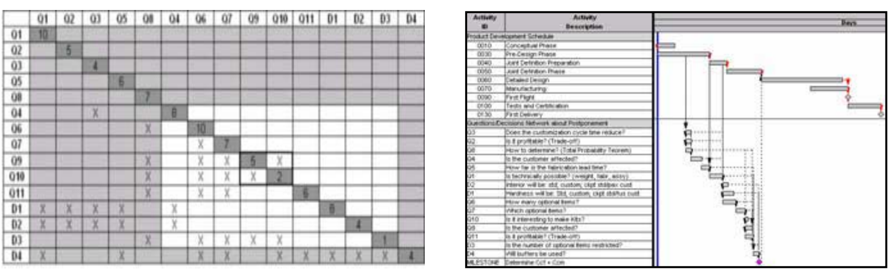
QFD Matrix 2	Parts Characteristics						
System Requirements	Std Hardness in ckpt and custom in fslg	Std structure	Std interior in ckpt and custom in fslg	Stk for interior and hardness	Stk for optional equipments	PA_{SR}	PR_{SR}
Light weight aircraft	3	3				2,54	17,22%
Wide scale production	3	3	3	9	9	3,96	26,89%
Flexible assembly line	9	9	3	9	9	4,21	28,61%
Low n° of components	1		1			1,21	8,23%
Standard assemblies	3	9	3			2,80	19,04%
G	5	3	4	4	4		
PA_{CP}	22,76	16,84	9,27	19,98	19,98		
PR_{CP}	25,62%	18,95%	10,44%	22,49%	22,49%		

Table 9. DTC Matrix for Alternative 2.

DTC Matrix	Parts Characteristics												
System Requirements	Std Hardness in ckpt and custom in fslg		Std structure		Std interior in ckpt and custom in fslg		Stk for interior and hardness		Stk for optional equipments		**Estimated Cost**	**PR$_{ER}$**	**SR Target Cost**
Light weight aircraft	1	92199,06	1	309746	1	99163,949	0	0	0	0	501.109	17,22%	520.105
	0,3		0,2		0,1								
Wide scale production	1	61466,04	1	464619	1	198327,9	1	35959,5	1	20587,5	780.960	26,89%	811.942
	0,2		0,3		0,2		0,5		0,5				
Flexible assembly line	1	122932,08	1	464619	1	198327,9	1	35959,5	1	20587,5	842.426	28,61%	863.953
	0,4		0,3		0,2		0,5		0,5				
Low nº of components	0	0	1	154873	1	99163,949	0	0	0	0	254.037	8,23%	248.495
			0,1		0,1								
Standard assemblies	1	30733,02	1	154873	1	396655,79	0	0	0	0	582.262	19,04%	575.005
	0,1		0,1		0,4								
	307.330		1.548.729		991.639		71.919		41.175		2.960.793		**3.019.500**

The DSM was used to solve the first part of the problem (see Box 1 of Figure 1), determining the relationships among questions and decisions. The first configuration of DSM elements generated a lot of interactions that usually increase cycle time and project cost. To optimize the DSM elements sequence, the Partitioning Algorithm [21] has been used. The resulting Numerical DSM, with activity durations (in weeks) in the matrix main diagonal, is presented in Figure 4a.

After that, the DSM data is transferred to the P3 software, to calculate the precedence network and incorporate it into the product development plan. The best time for the questions and postponement decisions to happen is, therefore, determined. Figure 4b shows the Gantt chart for the questions, decisions and the product development phases. Figure 4b, does not present numerical values to preserve the company's confidential information.



(a) (b)

Figure 4. (a) Final DSM after Partition Algorithm applying (b) Network for questions, decisions and product development

3. Discussion

In the first part of the problem, the DSM method, jointly with the CPM techniques help to determine the best schedule to make the decisions about postponement strategy usage to produce an aircraft, during the product development phase. The schedule of these elements is done respecting some constraints as technical information like market requirements, product and manufacturing requirements, preliminary supplier data and product maturity.

The final milestone, of postponement strategy definition, shall occur until the end of the Joint Definition Phase, because the Detailed Design Phase needs to start with this definition.

In the second part of the problem, focus of this work, by observing the precedence network results for both design alternatives, Alternative 2 presents 1413% of customization cycle time reduction if compared with Alternative 1. The major part of this gain is due to the strategic buffers usage for the optional items. However, for Alternative 2, these stocks are feasible just because the hardness and furnishing design was changed and the creation of optional kits after market statistic study. This action contributed to reduce the number of optional items, eliminating those ones with less demand. Then, the stock size was reduced, decreasing the inventory costs to acceptable levels.

The standard hardness design in cockpit and customized in fuselage, for Alternative 2, did not affect the aircraft's weight significantly, because the standard hardness length in cockpit is short, thus the aircraft operational cost was not affected.

The standard cockpit hardness and furnishing design created opportunities to reduce installation times, because the learning curve tends to fall quickly considering that more repeated activities occur.

Alternative 1, although having lower material costs compared with Alternative 2, derived a higher total cost, because the non-conformities costs (non standardized design) and aircraft reconfigurations (high customization cycle time) contribute to exceed the target cost. Further, observing data in Table 6, it is possible to note that the cost distribution is not suitable for Alternative 1, i.e., the systems requirements which have minor importance to customer are presenting higher costs.

Comparing data in Tables 6 and 9, it is possible to verify that Alternative 2 has presented 18.6% of estimated cost decrease in comparison to Alternative 1.

Alternative 2 presented not only the lower total cost (1.9% below the target cost), but its better distribution, associating the higher costs with the most important systems requirements for customer.

4. Conclusions

The design Alternative 2 revealed that the postponement strategy can be profitable to the company, because it increases significantly its flexibility to meet the demand fluctuations of the global market, reducing high reconfigurations costs, without losing focus on customer needs.

Conclusions are that the proposed method met the objectives fully. The best design alternative was determined, not only from a cost point of view, but also according to a customer value point of view by using QFD and DTC. A postponement strategy was defined by the alternative selection and the decisions, questions and milestones were scheduled during the product development phase by using DSM and CPM.

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Leading the Web in Concurrent Engineering
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Concurrent Engineering and the Dynaxity Approach. How to Benefit from Multidisciplinarity

Tom TILTMANN[1], Uschi RICK[2] and Klaus HENNING[3]
Center for Learning and Knowledge Management and Department of Computer Science in Mechanical Engineering (ZLW/IMA), RWTH Aachen University, Germany

Abstract. Some authors (i.e. [1]) claim for an appropriate organisational realisation of concurrent engineering. As the pressure to realise and maintain competitiveness in turbulent environments grows, organisations need processes and methods to deal with this challenging situation. This paper will examine the complexity in today's software development processes and present ways to cope with it. For that purpose, approaches of different disciplines are presented: concurrent engineering, multidisciplinarity and the dynaxity approach that categorises the behaviour of organisations into four zones. An approach will then be proposed that combines these three elements. It will be revealed by the example of a network project *KONVOI* in order to prove that this approach succeeds in turbulent environments.

Keywords. Concurrent engineering, software development, multidisciplinarity, agility, dynaxity.

Introduction

Software development takes place in an increasingly complex and dynamic environment. Hard and software technologies change very fast; innovative applications are continuously developed; new classes of customers are accessible; there are many new suppliers, companies and cooperations and some companies grow "with breathtaking speed" [2]. In complex and dynamic situations requirements, technologies and competition products change rapidly and unpredictably [1]. Hence, there is a strong need for efficient methods and processes to cope with these turbulent situations in software development. The following section highlights two overlapping approaches aiming to solve this problem: concurrent engineering and multidisciplinary. After that, an approach of organisational development is presented that describes the behaviour of

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[1] Dipl.-Ing. Tom Tiltmann: Head of department, Center for Learning and Knowledge Management and Department of Computer Science in Mechanical Engineering (ZLW/IMA), RWTH Aachen University, Dennewartstrasse 27, 52068 Aachen, Germany; Tel: +492418091140, E-mail: tiltmann@zlw-ima.rwth-aachen.de.
[2] Uschi Rick M.A.: Research Assistant, ZLW/IMA, RWTH Aachen University.
[3] Prof. Dr.-Ing. Klaus Henning: Director, ZLW/IMA, RWTH Aachen University.

organisations (from static to chaotic dynamics and from low to extreme complexity). The approach is then embedded to agile software development. Combining these approaches from computer science, sociology and organisational development allows to cope with turbulent situations. The KONVOI project is presented as an example in order to prove how this combination can be successfully applied.

1. Handling of Complexity

1.1. Concurrent Engineering in Software Development

Linear development is the basic model of software development. It separates the different development stages. The consequence of this approach is illustrated with the development steps - concept and implementation[4]. In linear development, the concept has to be kept constant before the implementation begins. But this requires a relatively long time in order to respond to the market and environment changes [2]. Hence, linear development is not capable enough to react to the turbulences in complex environments in an appropriate time. One approach to tackle these turbulences is concurrent engineering.

Concurrent engineering is an approach for simultaneous and integrated product planning. In contrast to linear development, this approach parallelises cross-functional (parts of) development stages in order to ameliorate the time flows. Furthermore, concurrent engineering aims at improving multidisciplinary team work and at a better integration of work contents [3].

In software development concurrent engineering is applied as follows [1]: The development begins with a preliminary architecture and a basic system description based on a product vision. The term *vision* is used to express that; due to the complexity of the environment no final specification can exist in this stage of development. Then a more detailed design is produced and implemented to the basic system. Iterative and in several small steps, this basic system is then continuously analysed, augmented and adapted to the real necessities [1]. Thus, analysis, implementation and evaluation of the software are done concurrently.

In complex and dynamic situations, this overlapping of development stages allows to react to rapidly changing requirements, technologies and concurrency products in a timely manner and for a longer duration. Considering the above mentioned example, in concurrent engineering, the concept development and the implementation would be parallelised in small iterations. Thus, the market changes e. g. could be taken into account very early and frequently. Advantages of concurrent software development are: reactivity, swiftness, punctuality and effectiveness. For this reason, concurrent engineering is considered “more appropriate for the turbulent environment” [2].

When different development stages are parallelised, different departments and disciplines that deal with these stages (like computer scientists for the implementation of the software and technical communicators for the usability tests e. g.) have to work closely with each other. According to [4], multidisciplinary team work is the key to concurrent engineering. It allows to cope with complexity and dynamics [5]. For this, the following section focuses on multidisciplinarity.

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[4] On purpose, these two terms shall not refer to any well known software development process here. They merely serve to illustrate the problem.

1.2. Multidisciplinarity in Software Development

Multidisciplinarity denotes the co-action of at least two disciplines. As the term multidisciplinarity is used quite heterogeneously, an open, less stringent definition is used in the context of this paper. Following [6], multidisciplinarity can be conceived as a kind of scientific co-action to develop contents and methods. This co-action aims at providing the most appropriate problem solving potential for joint objectives by cooperation of qualified scientists from different professional origins [6] according to [7].

Interdisciplinary work means working in teams with scientists of different disciplines having joint aims, and focussing on common questions. Thus, high demands have to be accomplished in interdisciplinary work. The demands can be characterized in terms of *consensus*, *synthesis* and *diffusion* [7]. The terms are being explained as followed.

Consensus means creating something new and mutual by integrating diverse perspectives. Thereby, this result applies for all involved. *Synthesis* stands for producing common results including a relevant and nameable contribution of all involved disciplines. Finally, *diffusion* means that all results have to be comprehensive, accessible and usable, and thus accordingly edited [8].

Concrete requirements can be derived from these demands: The criteria and standards for interdisciplinary projects represent [9]:

- conjoint definition of goals,
- conjoint development of questions,
- common language,
- common perspective or comprehension of the problems,
- conjoint acquiring of methods,
- competence contribution of all involved,
- synthesis of the results and
- edition of the results as appropriate for the target group.

Furthermore, working in multidisciplinary teams demands additional requirements concerning successful project management and teamwork [8].

Successful multidisciplinary work allows gaining special knowledge and abilities that transcend disciplinary limitations. It is possible to obtain new application fields and additional perspectives and furthermore, methods and theories of a discipline can also be advanced [9].

Section 1 contained two approaches dealing with complexity. As software development is carried out in most cases within organisations, it is necessary to consider approaches of organisational development, too. For this, the following section presents one interesting approach of Henning [10] in which agile software development can be embedded.

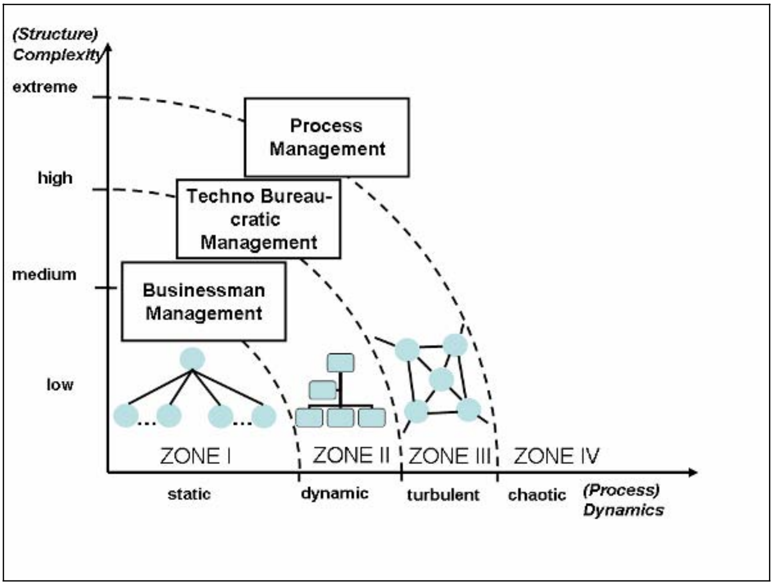

Figure 1: Behavior of organizations or companies in dependence of environmental conditions (according to: [10])

2. The Dynaxity Approach

2.1. Dynaxity of Organisations

The term *dynaxity* is composed of "dynamics" and "complexity". It combines both the dynamic and complex character of the environment of an organisation [11]. The approach categorises the behaviour of organisations into four zones [10]. The idea is illustrated in Figure 1.

In zone I, the complexity of work steps is low and the dynamic of the environment is static. In zone II the complexity and dynamic are a bit higher. Organisations in this zone are characterised through division of labour and standardisation and allow mass production by a "techno-bureaucratic" management. Complexity and dynamic raise in zone III as well as the unpredictability of economic, technical or political changes. Analysis and plans ahead of schedule become more difficult. In Zone IV the complexity is extremely high and dynamics are even chaotic.

The ability of an organisation to cope with more complex and dynamic requirements of the environment is called *dynaxibility* [11]. Multidisciplinary team work, e. g. allows to cope with dynaxity and to remain capable of reacting in these situations [5]. The following subsection embeds the dynaxity approach in agile software development.

2.2. Dynaxity in Agile Software Development

Since the early nineties, several new approaches of software development have evolved that aim at an avoidance of producing many artefacts with a lot of effort within the process. These so-called *agile* processes allow flexible reactions to changing requirements of the customer and to realise the maximum of the goodwill at any time

[12]. In 2001 representatives of the new agile approaches met in order to formulate common values of agile software development:

- individuals and interactions (more important than processes and tools),
- running software (more important than comprehensive documentation),
- customer collaboration (more important than contract negotiation) and
- responding to change (more important than following a plan) (www.agilemanifesto.org, seen on: 2006-03-28).

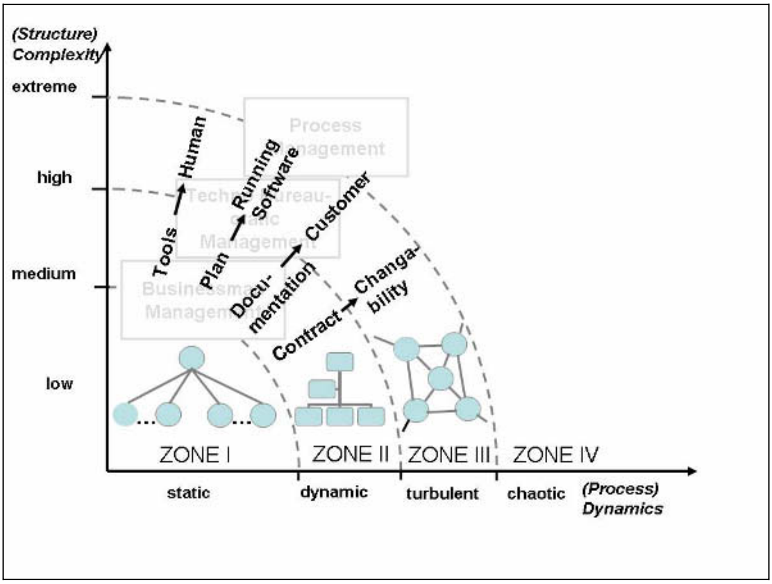

Figure 2: Agility as ability to cope with growing complexity in software development processes (according to: [12])

One method that implements these values is, for example, Extreme Programming (XP). It postulates the close and direct cooperation with the customer as its main goal [12].

The dynaxity approach (see Figure 1) reflects the change from dynamic (zone II) to turbulent or even chaotic situations (zone III/IV). As the values of agility indicate, this change also appears in software development [12]. Figure 2 shows how these values can be integrated in the dynaxity model of [10]. Similar to dynaxity, the ability of a software development company to cope with complex products and environment conditions is referred to as *agility*.

3. Combination of the Dynaxity Approach, Concurrent Engineering and Multidisciplinary

The previous two sections presented three approaches that aim at coping with complexity and dynamics of today's software development: concurrent engineering, multidisciplinarity and dynaxity/agility. These ideas come from multiple disciplines:

computer science, sociology and organisational development. In order to profit from the advantages of all these approaches in software development, it is necessary to combine them. Section 4 proposes one possibility to do this, and exemplifies it with a case study of the network project KONVOI.

4. Case Study: Software Development in KONVOI

4.1. The KONVOI Project

In the German funded network project *KONVOI* (2005-2008) it is being investigated by the Aachen University whether increasing efficiency on road transportation may be achieved by developing Intelligent Transportation Systems comprising Advanced Driving Assistance Systems. The objective of KONVOI is the development and evaluation of *truck platoons on motorways* to be implemented in commercial use by freight forwarding companies. It is planned to have virtual and practical driving tests by using experimental vehicles and a truck driving simulator. Thus, the impact of truck platoons on traffic is going to be analysed.

4.2. Concurrent Engineering

Concurrent engineering is well-anchored in all parts of KONVOI. The application of this approach is exemplified by the research areas software development and acceptance concept as these are of special importance in the project.

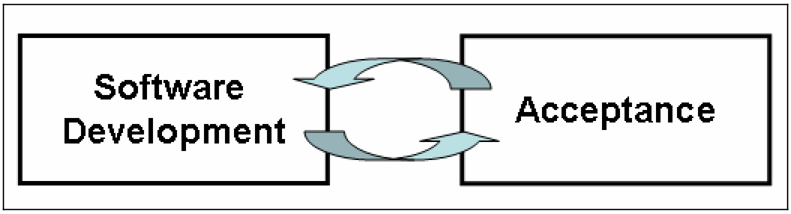

Figure 3: Interaction of software development and acceptance in KONVOI

Each software development process in KONVOI is iterative and has an individual length of development cycles. Some software pieces are developed in cycles of one week. Concurrently, the acceptance of the systems is investigated with truck drivers, forwarders and other traffic participants. These tests are carried out within each iteration using different quantitative and qualitative methods, at first with user interface prototypes and then with software prototypes. The results are continuously integrated in small steps into the software development process, as illustrated in Figure 3. Thus, the changing requirements can be taken into account as soon as possible. This approach is designed to meet the exact necessities. Furthermore, the acceptance tests turn out to be the tie between developers, users and sociologists.

4.3. Multidisciplinarity

KONVOI has an overall plan that defines work packages, their time budgets and milestones. This plan was jointly defined so that all involved disciplines can contribute their competency.

Each part of this development process is conducted individually. The interdependencies of different software pieces require frequent consultations with other engineers. These multidisciplinary consultations occur demand-oriented and self organised. Occasionally, they are triggered or complemented by bigger workshops that are organised by the project coordination. Multidisciplinarity, which is firmly implemented as the teamwork for software development and acceptance, is organised by regular meetings and workshops. Due to this organisation, the involved disciplines may, for example, develop a common perspective or comprehension of the problems and jointly acquire new methods to solve these problems.

4.4. Dynaxity and Agility

Complexity and dynamics rise in zone III of the dynaxity approach [10]. As seen above the unpredictability of economic, technical or political changes, as well as analysis and plans ahead of schedule get more difficult. In KONVOI, a detailed specification of the overall system and its subsystems was not possible in advance due to the lack of experience with truck platoons. So KONVOI could be classified as a zone III project. The following criteria for projects of zone III firm up this appreciation:

- the high number of involved engineers working together cross-departmentally,
- the work with further disciplines, like technical communication, sociology and psychology,
- the high number of users,
- the degree of dissimilitude in the users and
- the political explosiveness of the topic “automated driving”.

In these turbulent situations the agility approach recommends to focus the common values of agile software development that were mentioned above. The human factor is highlighted in KONVOI by using multidisciplinary team work (see section 4.3). This allows amongst others to cope with dynaxity and to stay capable of reacting in these situations. Running software is achieved by small development cycles, prototypes etc. The customer is integrated very early: The requirements engineering is done jointly with customers and operators. And the acceptance concept, which is realised through concurrent engineering, involves them frequently and in several iterations, too. Finally, KONVOI effectuates the changeability that is also achieved by concurrent engineering.

5. Conclusion

This paper integrates multidisciplinary approaches that aim at managing the challenge of complex and dynamic environments. It was shown that this approach can be used successfully in a complex and time critical project.

The approach has many consequences for the participating assistants. They do not only have to implement the common values of agility. Furthermore, the whole management structure has to be adapted to concurrent engineering, multidisciplinarity and to the dynaxity/agility principle for turbulent processes with a high structure and process complexity. KONVOI exemplifies that the new approach can be successfully combined, and allows amelioration of the process and product quality of software development projects in turbulent situations.

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Characterization of a theorical learning network for innovative design for small and medium-sized firms

Nicolas MARANZANA, Nathalie GARTISER
INSA Strasbourg Graduate School of Science and Technology
Laboratoire de Génie de la Conception (LGECO)
24 boulevard de la Victoire - 67084 Strasbourg Cedex

Abstract. Within the present environmental context, SME have to cope with a lack of resources, which prevents them from being efficient as far as innovation is concerned. Indeed, SME have to innovate so as to remain competitive and survive. But, in order to innovate, they have to acquire additional knowledge and skills which they do not possess. In order to fill this gap and to be efficient, it seems judicious to gather the SME so that they can share their knowledge and skills both by learning from one another and learning together. The network seems to be a privileged place since it makes enterprises cooperate in a unifying project although they do not have the same logic. But suggesting the network as an efficient alternative is not enough, it has to be defined. The aim of this article is to define, from a theoritical point of view, the general characteristics that this network requires for the learning of innovative design.

Keywords. Design, innovation, networks, learning, process

Introduction

Within the present environmental context, competition being now on an international level and getting more and more important, prices, quality and time can no longer give any advantage since all the serious competitors are efficient on these three points [1,2]. Today, the aim of many enterprises is to develop their innovative ability and especially their ability to innovate quickly [3].

In this paper, we shall more particularly consider the SME. In order to survive and develop their activities in favour of innovation, they will have to broaden and increase their knowledge and skills; they will have to consider innovation as top priority in their strategy.

The main stake will consist in finding enough resources to innovate in the SME. In order to achieve this goal, it might be interesting *"to look for new skills outside and to unite so as to create complementarities and invent multiple combinations in order to increase their knowledge"* [2]. It will be necessary to create a methodology of work that will make innovation come out through confrontation and enrichment of ideas.

The aim of this paper is not to focus on the solving of a specific problem, but more on the ability of small companies to increase their knowledge and their capacity to solve problems. That is why we propose the network as an interesting way to solve this specific problem of SME.

Starting from the present environmental context and its problems, this article aims at defining in the first place a methodology of work which will stimulate innovation; three points (innovative design, learning and network) enabled us to open onto the concept of a learning network for innovative design. Yet, suggesting this network is not enough, it has to be defined. That is why, in the second place, we shall present the criteria and explain the characteristics we have chosen as well as the methodology that has brought us there. To conclude, we shall see the stakes and prospects that this work offers.

1. From the environnemental context to the learning network

1.1. The context

Our starting point (i.e. the necessity to devise learning networks for innovative design) lies on the following logic : in order to innovate, enterprises must increase their ability to innovate so as to be able to apply processes of innovation (that it will have previously learnt) to projects of innovation ; to increase it ability to innovate, the enterprise must master different knowledge and skills (job, managing, methodology).

Our main aim with regard to this work is to provide support for the SME in order to develop their innovation in the long run. From ends, our aim is mostly to help them to increase their methodological skills (even if we take the other points into account). That is why we try to develop the knowledge and skills of the SME regarding innovative design. To reach its target, the enterprise has to learn methodology of course, but it also has to learn how to integrate in its process of decision the consequences of its choices as far design and innovation are concerned (about its organization, structure, and its competitors for instance). In order to learn, the enterprise has different resources (it can take part in specific training, it can ask the help of a consultant, …). Considering the SME have limited resources, we think it is important to increase the efficiency of the learning processes. That is the reason why we insist on the fact that the increase of skills in the SME as far as innovative design is concerned must be achieved with particular means especially adapted to their characteristics and which are different from those of bigger enterprises. We shall now consider how the three points (design, learning and methods of organization) have enabled us to come to the suggestion of a learning network for innovative design.

1.2. Three points : design, learning and methods of organization…

1.2.1. Design

The 1988 AFNOR standard (NF X 50-127) suggests the following definition for design : "Creative activity starting from expressed needs and existing knowledge and ending in the definition of a product which fills these needs and which can be industrially produced".

Four kinds of design come from literature [4,5]. They are traditional design, re-designing, creative or traditional design and innovative design. Considering this typology and with the aim of increasing the ability to innovate of the SME, it seems most important to try and increase the knowledge and skills of these enterprises as far as innovative design is concerned, because they are the ones that will give the

enterprise important competitive advantages. Indeed, the aim of innovative design is to find a new solution that will be able to modify the present artefact system, either in competing with this system or in supplementing it efficiently. It is interesting to adopt methodologies enabling to develop activities of innovative design because they enable the enterprise to do all it can in order to favor and ensure - as early as in the design process - the future adoption of the innovative product, process or organization by the market so as to open onto real economic performances [6]. All the difficulty and interest of this type of design lies there.

However, the SME have to learn those methodologies enabling to develop activities of innovative design [1] before learning them [2].

1.2.2. Learning

Learning is one of the most effective ways the enterprise has to progress (and thus to survive) in the present world. It is the learning which will make it possible to acquire and to increase knowledge and skills necessary for innovation. This learning is linked to the individual who is very often an essential element enabling to make the difference with the competition [7].

Three levels emerge from literature dealing with learning : individual learning, collective learning and organizational learning [8-10].

Individual learning is based on knowledge and past experiences, motivations and interests of each individual ; every one is responsible for his own learning. Within the framework of the collective learning, it is not only the individuals as such that progress in the understanding of a problem, but the whole team they form. Indeed, when an individual shares what he knows, it is the whole team which learns and progresses. Organizational learning, broader, includes various phenomena concerning the whole enterprise (the organizational system, the management method, the procedures and practices of human resources management, corporate culture, …). Organizational learning starts when the enterprise acquires skills known as useful for the organization.

In this work we want to combine those three types of learning, and to create a new corporate culture (in order to encourage all the members to learn permanently), and to create contexts of work enabling everybody to fulfil oneself. The aim is to support the emergence of processes helping the development of innovation and creation in the enterprise. The concept of learning organization is a good illustration of this subject.

First of all, it seems interesting to clearly define the word "learning". "Learning", indicates the voluntary increase in the individual and collective capacity to learn, by a total engagement, which transforms the individuals in their behaviours and their beliefs [11].

The concept of learning organization, born in the end of the 80s, represents an alternative to the traditional modes of management [7]. The learning organization mixes the individual, collective and organizational learnings. They are integrated because there are strong synergies between them [9].

The learning organization can be characterized, in a general way, like a *"continuous learning of its members, within the framework of a global vision of the organization, which connects the individual and collective learning in order to improve its economic, social and human performances"* [9]. The concept of learning

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[1] Methodologies and activities remaining to build precisely for SME, which will be detailed within the posterior framework of research.

[2] Beyond the contents of the learning, the methods of this learning will be defined later on.

organization essentially consists in creation, maintenance and development of corporate culture and work contexts, to encourage all its members to learn permanently, in order to make them more efficient. This concept seems particularly interesting because it uses the learning potential of each individual and each team, to fulfil the objectives of the organization. Moreover it supports the emergence of processes aiming at developing innovation and creation within the enterprise [9,10].

So, we try to set up, support and increase the learning phenomena in the SME. Centered on our issue, we want to develop "learning process" i.e. the capacity of learning (the effective increase of knowledge and skills but also the development of the capacity to learn) in the field of the innovative design.

The idea that we seek to defend here is the SME, because they have limited resources, do not have always the possibility, to work on the development of their design activities (whether innovative or not), on the one hand, nor, on the other hand, to develop their ability to learn. It would thus be useful to find original modes of organizations, enabling the SME to develop their ability to learn innovative design.

1.2.3. Different possible modes of organization

According to Josserand [12], four modes of organizations emerge. Indeed, Jarillo [13] enlarges the concepts of market, bureaucracy and clan introduced by Ouchi [14,15], to the network concept. These notions can be characterized on the one hand by their relationships (cooperation or not) and on the other hand by the existence or not of hierarchical relationships [13] (cf. Figure 1).

	No cooperation	Cooperation
Non hierarchical organization	Market	NETWORK
Hierarchical organization	Bureaucracy	Clan

Figure 1. *"Four modes of organization"* [12]

Let us see what led us to focus on the choice of the network as the correct mode of organization. In this work, market and bureaucracy, modes of organization that are not based on cooperation, are not adapted to the will of members from different enterprises to cooperate. The market is based on a system of price including all the needed information for the transaction. In the bureaucracy, there is the recognition of a legitimate authority which has an impact on the strategical orientations of the enterprise.

Moreover, the presence of hierarchy, like in bureaucracy or clan, is an important hindrance for learning process and change [9,16]. Indeed, it annihilates creativity, thinking, initiative, motivations and has an impact on individual performance [17]. These three modes of organizations (market, hierarchy and clan) are not adapted to our desire to favour learning in cooperative relationships.

But, the network that is characterized as a coordination system of heterogeneous players, which develop transaction based on cooperation, with the aim of reach together a shared goal [18-20] seems to be the priviledged mode of organization, enabling different companies to cooperate in a non hierarchical structure, around a unifying project. The network is also considered as an intermediary organization, between

cooperation and competition [21,22]. Indeed, partners in some projects can, at the same time be competitors on other markets.

The SME, in order to be efficient, have to rely on resources supplementing and going beyond what they already possess, thus leading them to re-consider their frontiers, to work and to cooperate together. This leads us to think about the design of innovative organization in order to increase the ability to learn and the acquisition of knowledge and skills of the SME, concerning innovative design.

1.3. ... which lead to the learning network for innovative design

The network seems then a strategic device, which can trigger off the collective learning process, enabling the SME to get involved in an innovative phase, which would be difficult to reach in an autonomous way.

Different networks with different goals emerge from literature and practice. For example, we can find information networks enabling an exchange of information and knowledge ; if we add a personal and relational dimension, the learning network, based on learning activity, is born. If we add a result targert, it becomes a co-production network, including a new aim : producing together [11].

The learning network enlarges then the concept of learning organization by taking into account people from different organizations, independent from a legal point of view, with the aim of creating a favourable organizational context, stimulating learning processes, creativity and innovation [23]. This network is focused on learning activities and gives an essential place to the enriching of knowledge of its members. This can be possible by the explicit and implicit passing on of knowledge, by sharing experiences or by enlarging thinking [11]. It enables to learn by practice, *i.e.* the confrontation of ideas, of knowledge or experiences between partners. This sharing of knowledge and the creation of new collective knowledge, thus enables each member of the learning network to increase his efficiency in his own project, and then to increase the global performance of his enterprise.

The learning network is thus as a place where the ability to learn how to innovate can emerge and develop.

2. Characterization of this learning network

2.1. Methodology

Based on previous presentation (on innovative design, learning and network.) we had searched to show the links between these different dimensions. Our aim was the characterization of a learning network for innovative design.

Figure 2 shows the way we made the recurrent dimensions appear ; obviously these dimensions seem from our point of view very important for this characterization.

If we want to be as sure as possible to be able to design this kind of network (which will allow SME to develop their ability for innovation) it is necessary to explore these networks. Indeed, in order to be able to devise this kind of network, it is fundamental to know about their characteristics, to build the specifications of what we will have to design and to define the generic characteristics which are needed for every network of this kind.

2.2. Presentation of the criteria

Starting from the global list of characteristics (which can be found in Figure 2), it has been necessary to organize them in the goal to point out a certain coherency needed for

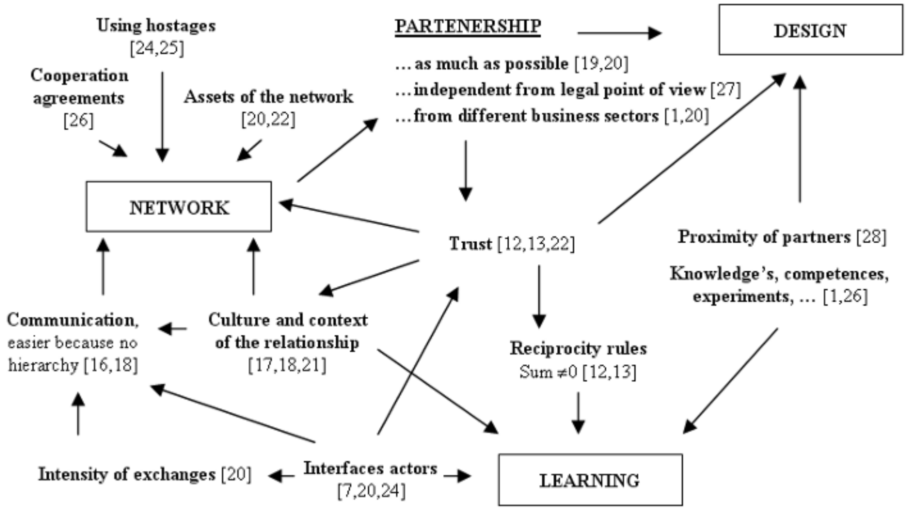

Figure 2. Methodology

the design of this kind of network. We decided to adopt the approach of Voisin, based on coherency [20]. In fact, in common sense, coherency is very close to the definition of a network of structures : it is a close link, logical and harmonious between different elements of a group.

Four kinds of coherency can be used to characterize a network :

- structural coherency : architecture of the organization,
- external coherency : coordination of activities between enterprises that are partners,
- internal coherency : fact that each member of the network is independent, and that all the members need a common organization because all of them have to be compatible one with the other,
- value system coherency : allows to unify enterprises in being sure that the links between them are stronger [20].

Starting from this, and from the analysis of previous scientific papers on this topic, a group of nineteen indicators, that can be observed and measured, has been identified. The two first columns of Table 1 point out the characteristics of a learning network for innovative design, and the possible values of those characteristics.

2.3. Wanted characteristics

The nineteen indicators enables us to characterize such a network. This innovative organization based on trust relationships between people is an original way to coordinate activities between enterprises.

But the nineteen criteria, as defined in Table 1, cannot alone help us to characterize a learning network for innovative design. Indeed, this criteria can have several values.

Table 1. Summary table about the wanted characteristics of a « learning network for innovative design »

19 criteria	Possible values *Non selected values*	Wanted characteristics of a « learning network for innovative design »
STRUCTURAL COHERENCY		
1. Structure	Formal, *Informal*	Formal
2. Exchanges between partners • What is shared ? • How is it shared ? • With which logic ?	 • All tacite or explicite knowledge • Personnal exchanges, using the learning network, *sum = 0* or ≠ 0 • Accumulated or *integrated*	 Id. Learning network Sum ≠ 0 Accumulated
3. Specificity of network's assets	High, *low*	High
4. Organization	Non hierarchical, *hierarchical*	Non hierarchical
5. Kind of partners	Owners of specific competences Owners of managerial resources Institutional facilitators Customers / Universities	Every kind of partners
6. Business sectors of the partners	Different, *the same or complementary* Partners' profile : endogamies or exogamies	Different, because it facilitates innovation Need to be determinate
7. Proximity of the partners	Geographic, electronic or the two	The two
8. Optimal number of partners	Minimum 2, maximum to be determinated	Id.
9. How are the links between the partners build ?	Personal will of the partners, *forced*	Based on voluntary
INTERNAL AND EXTERNAL COHERENCY		
10. Communication between partners ?	Same hierarchical level, common language and culture, communication and exchange tools (TIC)	Any communication tool
11. Intermediary actor ?	Yes, *No*, its job	Yes, animator of the network
12. Autonomy of the partners ?	Autonomy, independency or inter-dependency	Id.
13. Agreements between partners ?	Yes, *No* Tacit or explicit, written or not Length of the agreement has to be determinated	Yes Level of the formalism and length to be determinated
VALUE SYSTEM COHERENCY		
14. Degree of confidence between the partners	*Defiance*, confidence, principal vector of the cooperative relationship	Important confidence
15. Management of opportunist behavior	*Confidence, control*, using hostages	Using hostages
16. Human relationships	High, *low*	High
17. Culture	*High diversity of culture*, built common culture and identity	Common culture to be built
18. Intensity of the exchanges and duration of the network	*Low*, high To be determinated	High To be determinated
19.Evaluation system of the performance of the network and recognition system	Experience of animator taken into account Recognition system forced or using the different approaches of the companies members of the network	Evaluation system has to be built Recognition system based on the ≠ approaches of the companies participating to the network

But according to the analysis sumarized in 2.1. and 2.2. we recognize that for being sure the learning network for innovative design works, some of the values are totaly non wanted. For example, the organization between the companies at the network can't be hierarchical, because we need trust and freedom to be involved in a learning process. That is why, when the network will be design, we have to be sure that we will have a non hierarchical organization.

In a last step, we delete the non wanted values of some of the characteristics (cf. third column of Table 1).

According to the identified characteristics for our nineteen indicators, the global picture of the learning network for innovative design can seem to be very general. It is important to precise that our aim, in the article, is not to keep the best criteria , but to exclude the characteristics which are totally not wanted. Indeed, we tried to identify and to determine the general criteria of such a network. These will be the resources which will allow us to design such networks. Indeed, these "general criteria" will be seen in the future steps of our research as resources for a specific activity, the design of such networks (activity which will be defined in future works). Even if we know that, in any case, for building learning networks for innovative design, it is useful to create trust and consequent exchanges, in specific situations (one given group of specific enterprises wishing to be involved in such networks), the way to effectively build trust or the exact contents of the exchanges can really be different.

3. Conclusion

Seeing that SME really need to develop their ability to innovate despite their lack of resources, we have seen that a more efficient solution could be their association with others in order to share and to develop together their knowledge and their skills in design, and especially in innovative design. The network seems to be a good place which enables enterprises with different logics, to cooperate so that they can develop their abilities to learn and to innovate. But suggesting the network as an alternative in the area of learning to innovate is not sufficient ; it is necessary to elaborate the specifications which will permit to design such networks. This article has then proposed, using nineteen indicators, to characterize the different aspects of this learning network for innovative design.

The characterization of this learning network, using common parameters, is just the first step of this research work. Indeed, the next step will be to define a real design process of such networks. Starting from this general picture, our main aim will be to build methodologies for designing specific networks for real enterprises that want to start a learning process for innovative design. Our aim is to propose more operational dimensions (our 19 criteria and their wanted values) to help the designer to design the learning network for innovative design.

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Design, Manufacturing and Services in CE

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The role of associations in CAD and PLM for handling change propagation during product development

T.G. TREMBLAY, L. RIVEST[1], O. MSAAF, R. MARANZANA
Dept of Automated Production Engineering, Ecole de technologie superieure, Montreal

Abstract. Current Computer Aided Design (CAD) systems can capture some of the design intent by creating associations between objects. This increases the productivity during product development, and helps maintain the coherence of the product definition when handling engineering changes. CAD systems establish some associations as well as their use at a rather low level of abstraction, e.g. a parallelism constraint. Product Lifecycle Management (PLM) systems, on the other hand, use associations at a higher abstraction level, generally between files. The associations handled by these systems do differ both in terms of abstraction level and formalism of the knowledge they encapsulate. Moreover, limited connections exist between the associations manipulated in both systems, so that handling change propagation in concurrent engineering remains an issue. In this paper, we propose a taxonomy and a model of the different types of associations required to support the set of tasks in the area of product development. The terms on which the taxonomy relies are: association, relation, link, and constraint. The proposed model, named RLC, uses the concepts of aggregation and decomposition to relate Relations, Links, and Constraints.

Keywords. Associations, Relations, Links, Constraints, CAD, PLM, RLC model, Change propagation, Change Management, Data consistency, Decomposition, Aggregation

Introduction

In today's competitive market, delays and production costs of new products are very important considerations. Companies overcome these factors by depending on approaches such as concurrent engineering. On the technical level, this requires management of a digital model of an evolving product, as well as the distribution of information in multiple files (CAD, Computer-Aided Manufacturing, CAM, tooling, etc.). To conserve coherence within this digital model, the implementation and effective management of a network of associations within each file, as well as between the files which make up the product model, is essential.

One should differentiate evolutions of the product definition during design from evolutions of released data. In the first case, a multidisciplinary design team works simultaneously on various aspects of the product, the definition of which is in progress. These evolutions can be called Corrections (Maurino [1]). In the second case, the

[1] Corresponding author: Louis Rivest, professor, ÉTS, 1100 rue Notre-Dame ouest, Montréal, Québec, Canada, H3C 1K3; louis.rivest@etsmtl.ca

evolution uses predefined processes and forms (Engineering Change Request, Engineering Change Order, etc.), and is called Modification (Maurino [1]).

The study of administrative mechanisms and processes concerning the use, and, eventually, the computerization of these processes, is related to Change Management [2, 3]. The study of the models, tools and methods through which the effect of an evolution can be evaluated, and eventually documented for each effected object, falls under the domain of Change Propagation. This article proposes a classification of associations in order to organize change propagation within CAD and PLM systems.

1. Current Systems

Engineering projects rely on a set of specialized software. CAD systems usually handle the product's design and development (authoring) aspects. PLM systems (Product Lifecycle Management) handle the management of the information generated by the development process.

1.1. CAD Systems

CAD systems manage the lowest-level associations, i.e. between geometrical entities or elementary numerical parameters. Extensive mechanical design projects, a trademark of the automotive and aerospace industries, generate hundreds of thousands of CAD files and, potentially, millions of associations or dependencies. A rigorous knowledge of the dependencies between the geometrical elements should allow for efficient change management. However, this is not the case. CAD systems overestimate the modified elements when a change occurs. Hence, automatic update functions of the associations between CAD files cannot be used in an industrial context because they imply the creation of new versions of too many files, often needlessly.

1.2. PLM Systems

PLM systems manage associations between files, based on information external to the CAD files that is mainly administrative in nature, such as the date of the last modification, the modification author, the file's maturity status (WIP, Approval pending, Released, etc.). Actually, PLM systems manage files as black boxes. In this context, they cannot possibly circumvent a modification impact to only the affected entities, and hence to only the affected files affected by the change. A modification in a file leads the PLM system, by "domino effect", to deduce that each file may be affected by this change. For example, a modification of a feature in a component changes the component, which in turn changes the component that uses it, and so on.

The associations managed by the PLM system are fewer than those managed by the CAD system. However, due to their very weak semantic content, their exploitation potential is greatly limited in regards to change propagation.

1.3. Interoperability Between PLM and CAD Systems

The CAD system is the content editor whereas the PLM system is the content manager. Even when the CAD and PLM systems are from the same software editor, their

interoperability is extremely weak. These computer applications do not provide an efficient solution to change propagation, be they corrections or modifications.

1.4. Objective of This Paper

Efficient change propagation is a fundamental business issue that relates to delays, quality and competitiveness. Understanding the roles of associations between geometrical elements, features, parts, products and processes is a key to solving this issue, and to reaping the benefits of modern CAD and PLM systems. The objective of this paper, which presents some of the work conducted by our research team [4], is to propose a common vocabulary, so as to characterize and analyze the role of associations in product development. Taxonomy of associations is proposed based on the knowledge they handle. From there, we propose the RLC model that coordinates the associations manipulated in CAD and in PLM systems, which would enable, in the long term, to better integrate CAD and PLM as well as to efficiently manage change propagation.

2. Review of Literature

Numerous papers deal with the role of relations during product development. These papers use quite a heterogeneous vocabulary, and have not yet reached a consensus.

In the context of an assembly, many authors [5, 6, 7] use the term *mating relation* to describe a dependency between two components within an assembly. The terms *against* and *fit constraint* are used to define the dependency type. An *against constraint* establishes a contact condition between two planar faces [8], while a *fit constraint* establishes a contact condition between a shaft and a hole [8]. Shih and Anderson [9] define the term *geometrical constraint* as a limitation of the value of an element's attribute in regards to itself or to any other element of the design, such as the position (coincidence, concentricity), the orientation (parallel, angle), etc.

Eustache [10] introduces four types of *constraints*: the dependency constraint, the relational constraint ($<,=,>,\neq,\leq,\geq$), the boolean constraint (logical operations : AND, OR, etc.) and the rule constraint. He considers the dependency constraint to be a dependency association between two elements. The relational and boolean constraints are related to mathematical functions and logical operators. Finally, the rule constraint is a trade-rule applied to an entity. This constraint is similar to the derivation link proposed by Giguère et al. [11, 12]. They both try to automate trade-oriented tasks. To reach this objective, Giguère et al. define the technological link as a link expressing a dependency between two information elements. He uses a derivation link, which encapsulates some knowledge, to automatically obtain a pseudo-imprint of a feature from the imprint of another feature, in order to automate a design task.

Similarly, Michaud establishes a persistent technological link between the model of an aerospace skin panel and its associated tooling used for the chemical milling. He demonstrates that a proper preparation of the models with the help of a trade-oriented methodology, typified entities and technological links (expertise carriers), allows for considerable time gain during change propagation, starting from the part and all the way to its associated tooling [13].

According to Shah and Mantyla [14], multiple constraints (form, dimension, orientation and position) are required to describe the relation between two features or

parts in the same assembly. For some authors [5, 14] a *link* aggregates many contact constraints in one entity, so as to increase the level of model abstraction. Mukherjee and Liu [15] discuss a *quasi-link*, the main objective of which is to describe geometrical relations (concentricity, perpendicularity, etc…) between two features. Their link definition is similar to the *constraint* provided by Shih and Anderson [9].

Zimmermann et al. [16] describe the logical link between two engineering objects (EO). They also describe the knowledge that allows the automatic instantiation of EO and EOR (engineering object relation) from generic EO and EOR. Laako and Mantyla [17] use the term *relation instance* to describe the link between an abstract object and each of its instances. Finally, Yassine et al. [18], in their discussion of the links between heterogeneous elements, use the term *relation*. They consider that a relation indicates a dependency between two elements without necessarily describing the dependency type.

Analyzing the literature, we observe that there is a need to establish a common terminology in order to organize various concepts in a general model. This is what we propose in the next section.

3. Characterizing and Organizing Associations for CAD and PLM

In this article, we propose to characterize and organize associations and the objects to which they are applied. Essentially, an association between objects indicates the existence of a dependency between them. An object, again, as defined by Maurino [1] is labeled a technical object (TO) and impartially indicates every useful identifiable element of a product, such as a part, an assembly, a function, etc. In this paper, a geometrical entity, a feature, a document, are also seen as technical objects, and a TO can represent a set of TOs, in a recursive manner.

3.1. Types of Associations

The PLM and CAD systems manage associations of very different natures. We have defined three types of associations that aim for an increased interoperability between PLM and CAD. We use the generic term Association to refer to any type of dependency regardless of its specificities.

Relation

A relation establishes an abstract dependency between TOs. A relation is not formalized enough for it to be used by a software tool to propagate a change. Therefore, its interpretation and use requires human intervention. The ‘representation link’ discussed by Maurino [1], associates a TO (such as a part node in a PLM structure) to a document (such as a CAD file) that describes it. A relation is generally managed by the PLM system. For example, a relation could contain the positioning of a part in relation to another part, expressed by a positioning matrix resulting from the design intent at some point in time. If one part changes, the relation itself does not suffice to propagate automatically the change and maintain design intent and model consistency.

Link

A link defines a formal dependency between TOs. It describes a specific know-how associated to a given task using a procedural language or an approach similar to artificial intelligence. A task is considered here as a small portion of a work to be performed (defining a feature in a part can be considered as a task in a design work). It can be implemented by software means and may require occasional human intervention. The derivation link described by Giguère et al. [11, 12], that creates a joggle at the intersection between a stringer and a frame is an example of a link that captures a specific know-how based on methodologies unique to the aerospace field. A link can be built inside a CAD system (using Knowledgeware or User Defined Features within CATIA V5) or outside by using the A.P.I. (Application Programming Interface). Thus, a link could, for example, correspond to a pin joint association between features (hole, shaft, etc.) of mechanical parts.

Constraint

A constraint represents a specific formal and indecomposable dependency between TOs. Constraints are handled by the application (in our case, a CAD system) that also manages the dependent TOs. The application makes them available, generally, via the A.P.I., a macro-language, or the user interface. They are, in a way, terminal level associations. A parallelism constraint between two lines is a typical example of this type of association. Consequently, the constraints are indecomposable dependencies used to create links. Thus, the pin joint (link) mentioned above is decomposed into coaxiality and planar contacts constraints between the geometrical elements of the two parts.

3.2. Some Association Properties

A set of properties has been defined to characterize associations. While some are conventional, others are more specific to the field of application at hand.

Cardinality

We adopted the accepted definition of the cardinality of an association, i.e., the number of objects used in the dependency. To be complete and flexible, the cardinality of the association m X n is supported by our model. The particular cases of injection (m X 1), surjection (1 X n), and bijection (1 X 1) are considered. This attribute is linked to the concept of granularity presented hereafter, as well as to the previously mentioned recursive decomposition of TOs. Thus, generally, an association relates two sets of TOs (m X n).

Direction

Direction describes the orientation of the dependency or the orientation of the information flow between associated TOs. The RLC model distinguishes four cases:

1. **Directional association.** An association is directional when the dependency allows for the respective identification of the set of target and reference (or destination and source) TOs, or, generally speaking, when the roles of two sets of associated TOs are different, and cannot be exchanged. For example, in the case of two lines associated by a parallelism constraint, if one line is identified

as a datum, it becomes a reference, and only the orientation of that specific line can be modified and propagated to the other line.

2. **Bidirectional association.** An association is bidirectional when the flow of information can circulate both ways through the association. This is the case when the target and reference TOs cannot be differentiated, i.e., when they have identical roles, and when modification of the state of one will impact the other. An example could be similar to the above, i.e., two lines associated by a parallelism constraint, except that no datum is identified. An orientation change of one of the lines impacts the second one. An association is also said to be bidirectional when the reference and the target objects play distinct roles that can be exchanged in the association, which implies that the semantics of the association can be inversed. For example, a diameter A associated to a diameter B, related by a ratio of 2 (B is twice the size of A). The inverse is also true: A is half the size of B. Conceptually, a bidirectional association is equivalent to a pair of inversed directional associations.
3. **Association without direction.** An association is without direction when it does not convey a flow of information between the associated TOs. This implies that the state of an object cannot be determined by the state of the associated object. For example, a sub-assembly A is associated to a sub-assembly B to compose a product. The association between both sub-assemblies is without direction. These associations are generally relations.
4. **Association with an undetermined direction.** The direction of an association is unknown as long as it has not been determined as belonging to one of the previous cases. This situation arises when an association used during the product development process has been identified but not characterized.

Temporality

Regarding time, an association is either persistent, transient or semi-persistent. According to Michaud [13], the massive use of persistent associations in V5 is a fundamental differences between CATIA V4 and CATIA V5.

1. **Persistent association.** Only the destruction or modification of the association brings an end to the dependency expressed between TOs. Persistent associations facilitate change propagation. In Michaud's work [13], persistent links, established between TOs of the part and of its tooling, support the automatic change propagation by capturing the design intent.
2. **Transient association.** A transient association only exists during the creation of the target TOs. Only the result is saved, not the acquiring mechanism. Such an association has, a posteriori, no usefulness when a change occurs.
3. **Semi-persistent association.** A semi-persistent association has limited effectivity in order to fulfill specific needs. The control of this effectivity applied to a composition relation (in a product structure) allows, for example, for a component to be informed that it will be used in the assemblies of a given series.

Aggregation and Decomposition

Aggregation is the grouping of a set of associations or TOs in one entity in order to facilitate its manipulation at a higher level of abstraction. Decomposition is the contrary operation. Aggregation and decomposition are recursive operations.

In the context of product development, we consider that relations are aggregated links, whereas links are aggregated constraints. Similarly, files (parts) are aggregated features, whereas features are aggregated elements. In practice, relations associate files, links associate features, and constraints associate geometrical elements.

The concepts of aggregation and decomposition, illustrated in figure 1, help bring a continuity (a transition) between the numerous constraints established between low-level TOs, generally managed by the CAD system, and the fewer relations between high-level TOs (files), managed by the PLM system. Indeed, in the case of current, large-scale aerospace and automotive projects, a current PLM system could not possibly handle the entire CAD system's constraints if they were to be exposed. Moreover, the mere knowledge of relations between files gives only minimal assistance in change management and is insufficient to consider any kind of automatic processing.

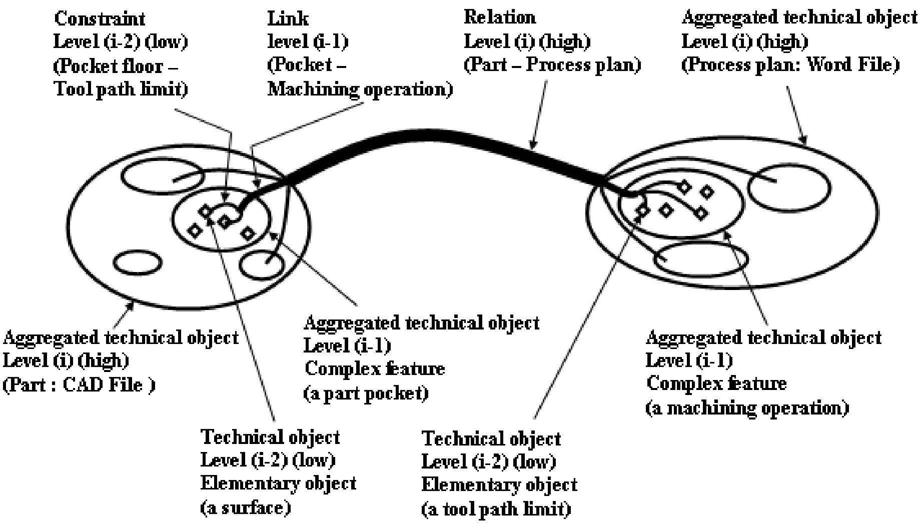

Figure 1. Example of aggregation/decomposition of associations and of technical objects

The RLC model gives designers a means to express design intents by handling links that encapsulate a trade-oriented know-how between TOs having a certain level of abstraction, that would afterwards be decomposed by the CAD system into constraints between elementary TOs. Current CAD systems allow designers, generally, to handle low-level constraints that only partially capture the design intent. Figure 1 illustrates an aggregation and decomposition example.

4. Conclusion

Current CAD systems primarily manage constraints established between elementary technical objects, to which links between more complex objects can be added. These objects are aggregations of geometrical elements, when UDF, Knowledge or VB are used. Current PLM systems used in industry primarily manage relations between files.

These various types of associations are characterized by the know-how they formalize or define: a constraint carries a highly formalized, fragmentary know-how,

whereas a relation conveys an abstract dependency. A link defines a formal dependency to which is associated a particular know-how that is specific to a given task. These three types of associations are characterized by the properties of cardinality, direction and temporality. Aggregation and decomposition make it possible to navigate between relations, links and constraints. In this context, the RLC model (Relation-Link-Constraint) positions the link at a satisfactory level for human interaction with the CAD tool, and establishes the link as an adequate way to achieve CAD-PLM integration, and allows for the eventual efficient change propagation during product development.

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Manufacturing Knowledge Management: Requirements for Preliminary Design

Sara MOUNTNEY and James GAO
Department of Manufacturing, Building 53, Cranfield University, Cranfield, Bedfordshire, UK, MK43 0AL.
Email: James.Gao@cranfield.ac.uk

Abstract. This research considers the use of manufacturing knowledge in the earlier, preliminary stage of design where the geometry is not so developed and where development of manufacturing technology may be required. An exploratory case study was carried out with a manufacturer of gas turbine engines for the civil aviation market. Semi-structured interviews were carried out to investigate the manufacturing knowledge required and its format. Using a data-driven analysis, a thematic code was developed and three themes emerged: manufacturing impact, expressions of impact and knowledge type. The resulting requirements for a knowledge management system to support the use of manufacturing knowledge in preliminary design are discussed.

Keywords. manufacturing knowledge, new product introduction, knowledge management.

Introduction

Information to support manufacturing process decisions needs to be available as early as possible during the design process to prevent increasing costs and risk as projects progress. In complex products, step changes in the design requirements to meet rising performance targets can result in the need for radical changes to component material properties, configuration and geometry. Often, new manufacturing technology processes need to be developed to achieve these geometries. Thus, a necessity in new product introduction in this sector is the ability to integrate knowledge of manufacturing technology innovations into the design process in a timely and appropriate way.

This paper outlines the requirements for a knowledge system which advises designers of the manufacturability of a product for the purpose of new product introduction, focusing on the sharing of manufacturing knowledge acquired during manufacturing technology innovation. Key to this is a measure of the maturity of the process capability during new manufacturing technology development. The requirements for the system have been derived from a review of existing research in the area and the results of an exploratory case study which investigated the nature of

manufacturing knowledge required by designers during the preliminary stage of the design process. The subject of the case study is a major manufacturer of gas turbine engines for the civil aerospace market.

1. Manufacturing knowledge - related work

The systematic approach to the design process described by Pahl and Beitz[1] is indicative of the methodological approach adopted widely in Europe and the US. Concurrent Engineering (CE) and associated techniques such as Design For Manufacture (DFM) aim to reduce the cost of the component and its developmental lead time by considering a proposed design solution in terms of ease of manufacture as early as is practicable[2,3]. However, with DFM there is an assumption that all the manufacturing processes selected are capable and proven. This does not account for the introduction of new manufacturing technologies and their effects on the product, a problem which this research aims to address.

Existing information systems developed for manufacturing assessment have concentrated on manufacturing process and capability. Sharma and Gao created an information system to assess manufacturability during the early design stages on an operation-by-operation basis[4]. The manufacturing options are compared by cost with no assessment of manufacturing capability. Balogun *et al* developed a knowledge management database to support manufacturing knowledge in design using a product model and an integrated process model[5]. Specific operations from the process model linked into the product model at component and feature levels. The database functionality includes assessment of manufacturing processes, costs and capability. Both systems rely on geometric definition of the component as a pre-requisite to its assessment and assume that the processes selected are mature and capable.

In this research, the use of manufacturing knowledge in the product introduction process is treated as a knowledge management problem. According to Polanyi, knowledge has explicit and tacit dimensions[6]. The explicit dimension can be codified and structured, whereas the tacit dimension is the 'knowledge in people's heads' which results from personal experience and cannot be codified. These definitions were extended by Nonaka in the 1990s[7], who proposed four inter-relating mechanisms for the transfer and building of organizational knowledge: socialization (the sharing of tacit knowledge between individuals), combination (the transfer of explicit knowledge), externalization (the transfer of knowledge from a tacit to an explicit viewpoint) and internalization (the transfer of knowledge from an explicit to tacit viewpoint). Polanyi and Nonaka's work offers an explanation to the industry problem that the information system approach to knowledge management has not produced the anticipated return on investment [8]. Information systems deal primarily with explicit knowledge at the expense of tacit knowledge transfer. Fahey suggests that a shared context needs to be created outside an ICT to enable the exchange of tacit knowledge because there is no substitute for a human interface[9]. Walsham also suggests that the human aspect of knowledge management techniques should be considered with ICT implementation[8]. He advocates the use of social techniques such as Communities of Practice and organisational translators to facilitate the sharing

and transfer of tacit knowledge. Other researchers have advocated the use of a sociotechnical approach to represent both tacit and explicit knowledge[10,11].

This research has some commonalities with the socio-technical approach in that the most effective methods (which may involve human interaction or IT tools) of manufacturing knowledge transfer will be considered. The development is therefore not purely technology-led but will consider the best 'fit' of methods appropriate to the knowledge and task.

2. An investigation of manufacturing knowledge in preliminary design

An exploratory case study was carried out to investigate the nature and extent of the manufacturing knowledge used in the earlier, preliminary stages of design. For the purpose of the investigations, manufacturing knowledge was defined as 'knowledge which relates to the manufacturing of a product which impacts directly on the design requirements or the outcome of the design'. The nature of design undertaken during this stage was adaptive, with new designs being derived from existing solutions. Semi-structured interviews were held with two sets of interviewees. The first interviewees were preliminary design engineers. The second set were engineers from departments which interface functionally with the central preliminary design department during the product introduction process. The interviewees were asked about specific situations where manufacturing considerations had impacted on the design requirements or design outcome. This could be either a positive or a negative effect. They were also asked about the source and format of knowledge. The interviews were recorded and transcribed and a code developed using a thematic coding technique[12].

The code identified three main themes which indicate the use of manufacturing knowledge in the design process:-

- Manufacturing Impacts;
- Expressions of Manufacturing Impacts;
- Knowledge Types.

Each theme and its subdivisions are described below.

2.1. Manufacturing Impacts

The manufacturing process ultimately constrains the size and configuration of the component being designed. The extent of this constraint can be described in increasing levels of detail, which are represented by these three sub-themes:

Configuration: The manufacturing process constrains the general size and configuration of the component, for example the minimum allowed wall thickness of a component due to the casting process.

Tooling**:** The manufacturing process constrains the size and configuration of the component due to tooling clearance limitations at component level. For example,

the geometry of the component is changed to allow clearance for machine tool paths during machining.

Manufacturing Geometry: Additional geometry needs to be added to the component geometry to facilitate the manufacturing process for a specific operation. For example, the geometry of the component prior to manufacturing includes additional blocks of material either side of the component for work holding.

2.2. Expressions of Manufacturing Impact

This second theme considers how the manufacturing impacts can be expressed to communicate design considerations during the product introduction process.

Empirical: The manufacturing process constraints may not be fully quantified. They must be assessed using combinations of expert judgement, experimentation, empirical numerical calculations and written/verbal comments. This method of expression is often seen when some process development is required. For example: a new joining method for two different materials and resulting discussions / communications related to this.

Quantified: The manufacturing process constrains the component to certain parameters or rules which are expressed numerically, for example, the minimum allowed wall thickness of a component due to the casting process.

Standardised: The manufacturing process constrains the size and configuration of the component to a predetermined list of discrete values, for example, the use of a previous part as a standard solution with no dimensional alterations made.

2.3. Knowledge Types

The final set of sub-themes demonstrates how manufacturing knowledge can be communicated throughout the product introduction process.

Structured: Quantitative knowledge which is documented in the form of parameters, dimensions, spreadsheet calculations, algorithms in expert systems or graphically. Knowledge is said to be ‘abstracted’ – it is possible (although not always preferable) to apply it without knowing its context. Examples: a graphically represented parameterised feature; a spreadsheet of calculations.

Semi-structured: A mix of qualitative and quantitative knowledge. The quantitative knowledge supplies the numerical value and the qualitative knowledge supplies the context. For example: details of material properties on an intranet site, project reports and emails.

Unstructured: This knowledge type is identical to semi-structured knowledge except for its method of communication. It is not recorded and is communicated socially, hence the expert being questioned supplies the context. Communicated using either formal or informal social networks. Examples: discussions with people; group meetings.

Structured and semi-structured knowledge conform to the definition of explicit knowledge. Unstructured knowledge conforms to the definition of tacit knowledge.

3. The concept framework for manufacturing knowledge

The themes were used to construct a concept framework to describe the manufacturing knowledge requirements in preliminary design. This is shown in figure 1 with the parts to the framework discussed below.

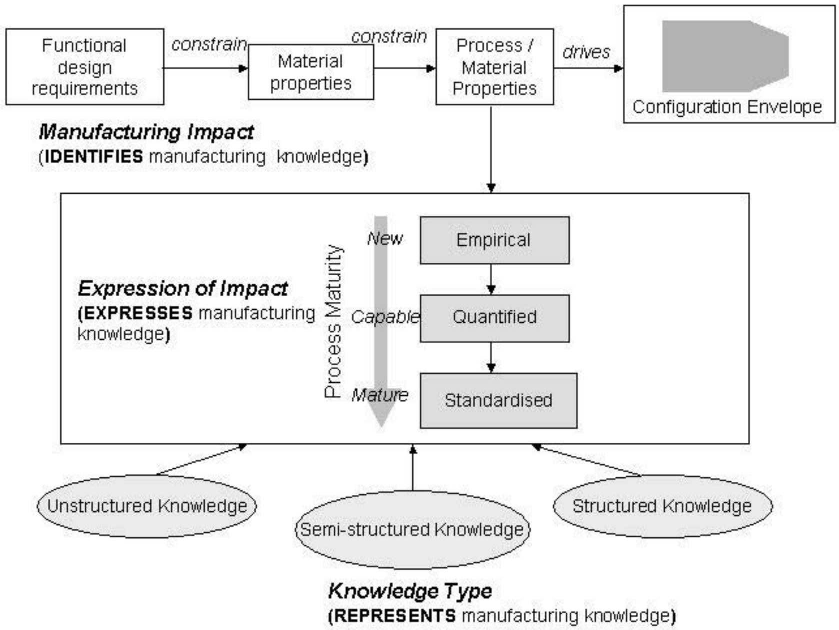

Figure 1: Concept Framework for Manufacturing Knowledge in Preliminary Design

The first part of the framework (the Manufacturing Impact) identifies the knowledge required by describing how the manufacturing process impacts on the design outcome. In preliminary design, constraints can be inferred by considering a previous component (and manufacturing process) as a starting point for the previous design. The properties of the material selected for the component (from the functional requirements) will constrain the manufacturing processes available to the designer. These constraints may have a positive or negative effect on design creativity. At one extreme, a manufacturing process could constrain component dimensions to the extent that they cannot be changed. Alternatively, the development of new manufacturing technology changes the available ‘configuration envelope’ for the component and makes new configurations and sizings available to the designer. The ability to share the configuration impacts influenced by tooling and additional manufacturing geometry from the detail stages of design in preliminary design would enable such information to become available earlier in the design process.

Once the manufacturing impact is established, it is necessary to find an effective way to represent this knowledge. These expressions of impact are shown in the second part of the framework. The data analysis indicated a link between an appropriate

method of impact expression and the maturity of the manufacturing process capability. If a method of manufacture is under development, significant trials and experimentation are required in ascertaining its feasibility for use. It may not be possible to express definite quantifiable rules for new components. Consequently, the empirical expression of impact would be the most suitable for expressing the manufacturability issues. Once some degree of maturity of process capability has been reached, the results of the experimentation can be expressed as rules, using the quantifiable method of expression. For a very mature manufacturing process, it may be possible to standardise the manufacturing process and hence the component/feature geometry into a discrete range of values. By using a combination of expressions of manufacturing impact and a method of determining the manufacturing technology development state, an indication of manufacturing process maturity can be fed back to the preliminary design stage.

Having identified the knowledge and its appropriate expression, the final part of the framework addresses the way in which this knowledge can be represented. The representation of knowledge using a combination of knowledge types is proposed. This is important because all knowledge types have strengths and limitations. Structured knowledge appears to be of particular importance during the preliminary stage (especially graphically), however it is important that a context is supplied otherwise it may be wrongly applied. A method of supplying that context exists with semi-structured knowledge, however the context of semi-structured knowledge needs to be known for searching and the knowledge may not actually be represented in the required context. Unstructured knowledge was the main method for exchange of knowledge, possibly because of the ability to supply context within a conversation. The benefits and efficacy of formal and informal social networks were widely evident. However, it is also necessary to record some aspects of the manufacturing knowledge and this must be carried out using a more appropriate knowledge type.

4. Proposed requirements of a knowledge management system

A knowledge system to support the use of manufacturing knowledge during the preliminary design stage should therefore meet the following conceptual requirements:

- The system developed should include, or link to some graphical representation of the relevant component configuration. The design process would commence by selecting a pre-defined generic CAD model for a preferred component style. This initial generic model would contain configuration boundaries which corresponded to manufacturing process constraints.
- The manufacturing process technology should be communicated in terms of constraints to the component configuration. Once the component was selected, the component material and primary manufacturing process (the main process to define the initial component configuration) could be selected. The system would then display the manufacturing constraints on the component configuration due to that process.
- The ways in which the constraints on the component configuration are expressed should be appropriate to the maturity of the manufacturing process

technology. The constraints would be displayed depending on the maturity of the manufacturing process. For example, maximum and minimum permissible dimensions would be displayed for a mature process where constraints could be quantified. In the case where a process was under development the current 'best assessment' would be displayed. This process would then be repeated for secondary manufacturing operations.

In addition to the manufacturing constraints, additional information on the manufacturing process, its capability, maturity and details of any development projects would be made available as a series of http pages which could be accessed via hyperlinks.

- The system developed should utilise all the knowledge types and therefore be a combination of information and social systems. It is appreciated that unstructured knowledge is not suitable for inclusion in an information system, however the system will feature contact names in the hyperlink as a method of facilitating the use of social networks.

The information is therefore filtered and represented to the designers using the different expressions of manufacturing impacts and knowledge types, as follows:

- Where the process is mature and capable, the manufacturing impact constraints are quantifiable or standardised rules shown as structured knowledge.
- Where the process is under development and the knowledge cannot be quantified as rules, the http hyperlinks will access semi-structured knowledge. These additional links can also supply extra background semi-structured knowledge to support initial structured knowledge.

Current work is now focused on the development of a knowledge system to support the use of manufacturing knowledge in preliminary design. There are two elements to this development. Firstly, the development of (a) social system(s) to facilitate the exchange of unstructured knowledge and secondly, the development of a prototype knowledge management IT tool to capture structured and semi-structured knowledge and to provide contact details to facilitate the creation of a social network (unstructured knowledge).

5. Conclusion

The research confirmed the importance of manufacturing knowledge during the preliminary design stage. It is necessary to consider the impact of the manufacturing process because this directly impacts on the achievable configuration and shape of the component. This can have a positive effect in that a new manufacturing process changes the component configuration envelope to enable different, more demanding design requirements to be met. It is necessary to assess this impact for early identification of manufacturing technology risks and opportunities. The impact of the manufacturing process can be expressed in three ways – empirically, quantifiably and

by standardisation. Each expression of impact is required to express the appropriate level of maturity for the manufacturing process. A knowledge management system to support manufacturing knowledge during the preliminary design stage must therefore represent the process impact and the three ways in which this can be expressed. Such a system must also represent knowledge across the tacit-explicit knowledge spectrum.

A prototype knowledge management system is now being developed using a socio-technical approach to represent both explicit and tacit elements of knowledge. This system will demonstrate the requirement for representing process maturity.

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Platform Module Design for Variety and Cost of Product Family

Tsuyoshi KOGA[1], Kazuhiro AOYAMA and Toshiaki NAMBA
The University of Tokyo, School of Engineering

Abstract. This paper proposes a design method of platform module for variety and cost of product family. A graph-based and computational model of product family, products and platform module is proposed. Based on the product family model, variety generation process is formalized as a design problem of parts and interface unification. The platform module design is represented as a module design that commonly used in all products in the product family. Decision making system for the platform module design is developed that can compare the value of product family, variety of products, cost reduction effect of platform modules and cost for design change. The proposed design method addresses: (1) how to formalize the product family and platform modules in the computational way; (2) how to evaluate the difficulty of design change, merit and cost of platform module and the variety of lineup; and (3) how to design the platform module that reflects a product family strategy.

Keywords: Platformization, Common Architecture, Product family model

1. Introduction

Various products are necessary to meet various customer needs in both of niche market and mainstream market. However, good balance of product variety and cost is difficult, because the product variety increases design and production cost. Platformization considering product family contributes to improve both variety and cost. The appropriate platform design is very difficult, because the platform module deeply depends on the topological structure of each product. Many constraints of the platform design must be considered, e.g. connections between components, integration cost, connectivity and modularity.

Today, many methodologies have been developed for the purpose of the product family design and the platform module design. Neison proposed the multi-criteria optimization method of the product platform seeing benefits through reduction of inventory, reduction in the proliferation of different parts, reduction in the design lead-in time for product *[1]*. Simpson developed an interactive web-based platform customization framework as an extension of product family design and presented a prototype system *[2]*. Raghothama proposed a topological framework for parts family *[3]*. They addressed how to generate members of parts family, and how to decide a given object belongs to an assumed parts family. The design method of the combinations and attributes of modules by the optimization method is proposed by Fujita and Akundi *[4] [5]*. Shiddique presented that a reasoning method of product family architecture considering the product family architecture and manufacturing

process *[6]*. Jonathan proposed the evolution model of products of the product family *[7]*.

The purpose of this research is the proposition of the platformization method that can support the design of appropriate platform module, based on try and errors considering various constraints, considering the factors of the product family.

2. Product Family Model

Table 1 shows the example of the platform design method. The designer can know the variety of product family by products in lineups. The design method shows the designer the module costs that are required for all products in proposed product family plan. The designer can design the platform modules by this platform design method. The design method outputs the products and modules in family.

Table 1. Comparison between Family Plan A and B

	Product Family				
	Current		Family Plan A		Family Plan B
Lineup products	3	<	8	>	3
Modules	12 A1 B1 C2 D1 A2 B2 C1 D2 A3 B3 C2 D3	>	7 C1 C2 D1 D2 D3 Platform A-1 Platform A-2	>	4 D12 D3 Platform B-1 Platform B-2

The product family consists of the products. The product family model is required for the design method of platform module, that is shown in Figure 1. The single product is modeled by entities, attributes and their relationships. The product consists of components, parts and sub-systems. These are represented by the entity *E*. The entity is represented by the attributes *A*. The structural connections between the entities are represented as the link *F* between the entities.

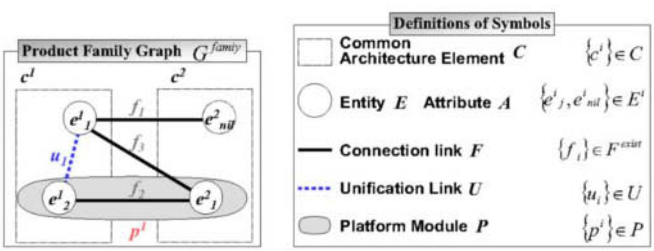

Figure 1 Product Family Model

The operation of the platform module design (= platformization) is represented by the combinations of the operation of the parts and interfaces unification. Hence, based on the product family model in Figure 1 and the operation of the unification, the platformization is formulated as that the new architecture element consists of the

platform modules that include entities that have connections between integrated common architecture elements.

3. Platform Module Design for Variety and Cost of Product Family

An overview of the platform design for variety and cost of the product family is shown in Figure 2. The main flowchart consists of following steps: an input current products <A>, the common architecture design and the generation of product family model <B>, the unification of parts and interfaces <C>, the platform module design <D>, an evaluation of lineup <E> and an evaluation of product family <F>. This loops of the design and evaluation from <A> to <F> are done by iteratively, it means that the evolution spiral of product family is designed by the computational models of the product family and the platform modules.

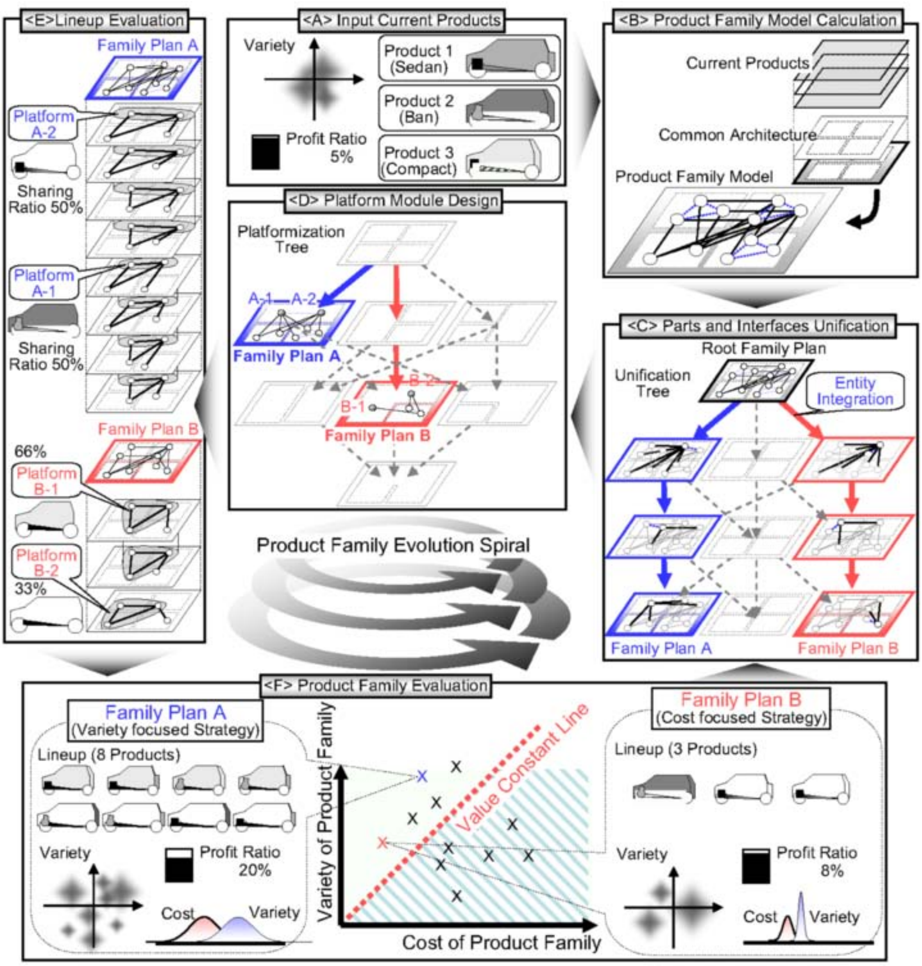

Figure 2 Overview of the Platformization Method

4. Information Processing Procedures

The product family model consists of the product models in lineup. Figure 3 shows the information processing procedures of the generation of the product family model. The detailed procedures are as follows:

STEP1 Input Current Product
STEP2 Set Common Architecture
STEP3 Add Relationships across Products
STEP4 Generate Product Family

The unification operation is operated on the product family model in Figure 3. Figure 3 shows the example of the unification operation. Two bodies B1 and B2 are integrated by the operation of unification. The new integrated body inherits the connection links and unification links.

STEP1: Integration of the entities
STEP2: Inheritance of the connection links
STEP3: Inheritance of the unification links

The proposed design method calculates the space of the unification plans automatically by using the unification links. Figure 4 shows the unification tree that includes all the unification plans and unification scenarios.

Based on the selected unification scenario, the parts and interfaces are integrated. Figure 5 shows the unification scenario of the Family Plan A in the Figure 4. Figure 6 is the Family Plan B.

STEP 1: Integration based on the unification link b1
STEP 2: Integration based on the unification link a1
STEP 3: Integration based on the unification link a2a3

Figure 7 shows the platformization result of the Family Plan A and B (Figure 7 [3]) by selecting a platformization plan in the automatic calculation result of the platformization tree (Figure 7 [2]) based on the structure of the common architecture (Figure 7 [1]). The detailed information processing procedures are shown as follows:

STEP [1]: Input structure of common architecture: The design system calculates the structure of the common architecture (Figure 7 [1]). Architecture interfaces (f1, f2,f3,f4) that connect the common architecture elements are defined based on the connection links between entities.

STEP [2]: Calculation of Platformization Graph: The design system calculates a platformization tree (Figure 7 [2]) automatically. The platformization tree represents the space of the platformization plans. The platformization tree can be calculated based on the cut-set of the common architecture graph (Figure 7 [1]). The platformization tree consists of platformization plan nodes and platformization links. The platformization plan node is defined as the matrix that consists of the architecture interfaces. Black painted cell of the platformization matrix represents the vanished architecture interface by the operation of the platformization.

STEP [3]: Platformization based on the Platformization plan node: The platform module design is achieved by the selecting one platformization plan node on the platformization tree [2]. Figure 7 [3] shows the platformization result of the Family Plan A and Family Plan B. In Family Plan A, the platform that integrates the body and underbody is obtained. The Platform A-1 for compact car is designed by the integration of the body for compact car and the universal chassis. In the same way, the platform A-2 for L-class car is designed by the integration of the body for L-class and the universal chassis.

The design system evaluates the product family plans. Each product family plan is evaluated by the following three aspects: (1) Variety of Product Family, (2) Cost of Design Change, and (3) Cost of Production.

Evaluation 1: Variety of Product Family: The variety of the product family is calculated by estimating the positioning of each product in the market. For example, Family Plan A has 8 products (Figure 5). Each product has the cover area in the market as its attributes. The variety of Family Plan A is evaluated by the positioning of 8 products.

Evaluation 2: Cost of Design Change: New costs for the development of the integrated entities are estimated. For example, Family Plan A has four integrated unification links (a1, a2, a3, b1) and two integrated entities (B12, A123). The cost of design change is estimated as the summation of the integration cost of the four links and the design cost of the two entities.

Evaluation 3: Cost of Production: The production cost is estimated based on the number of the modules. For example, the platformization plan [P1a] in Figure 7 [3] has 7 nodes, so the number of the modules is 7. In the same way, the platformization plan [P2b] in Figure 7 [3] has 4 modules. The production cost can be reduced by the mass effects based on the reduction of the number of the modules.

The design system calculates the modularization point and platformization point as the platformization guideline. The modularization point is calculated by the summation of the modularity for each module. All modules can be calculated by the cut-set of the product graph automatically by the design system. The platformization points are defined as the summation of all modularization points in the product family model.

5. Discussion

The Family Plan A and Family Plan B have quite different strategic directions. The biggest merit of the Family Plan A is the variety of its products (8 products, Figure 5 [F1c]). However, the number of the modules (7 modules) is not reduced so much than the Family Plan B as shown in Figure 7 [P1a]. To the contrary, the biggest merit of the Family Plan B is the reduction of the production cost (Figure 7 [P2b]). However, the Family Plan B has only 3 products on its lineup as shown in Figure 6 [F2c]. Table 1 indicates that the designer can design the appropriate product family plan that reflects product family strategy, by comparing with alternative candidates from the viewpoints of the variety of products and total cost of product family. Hence, the platform module design method proposed in this research can surely improve the value of the product family by balancing of the variety and cost.

6. CLOSING REMARKS

The design method of the platform module for variety and cost of product family is proposed in this paper. The design system can support the designer to compare the platformization plans by automatic calculation of the solution space of the product family, and by estimating the variety of products and cost of design and production. The to-be design method of platform module design is proposed by comparing platformization plans for taking various constraints and the whole product family growth into consideration. The integration of interfaces and introduction of common

architecture used to be effectively worked in the car industries and computer industries. In the near future, the proposed platform design method will be effectively used to design a to-be model of a common architecture and a direction of the interface integration in the software industries and web-based service providers.

Future studies are needed to investigate the following issues:

1) Introduction of a multi-phased platform design method
2) Integration with the various evaluation models of modules
3) Expansion for a product life cycle design method

ACKNOWLEDGEMENTS

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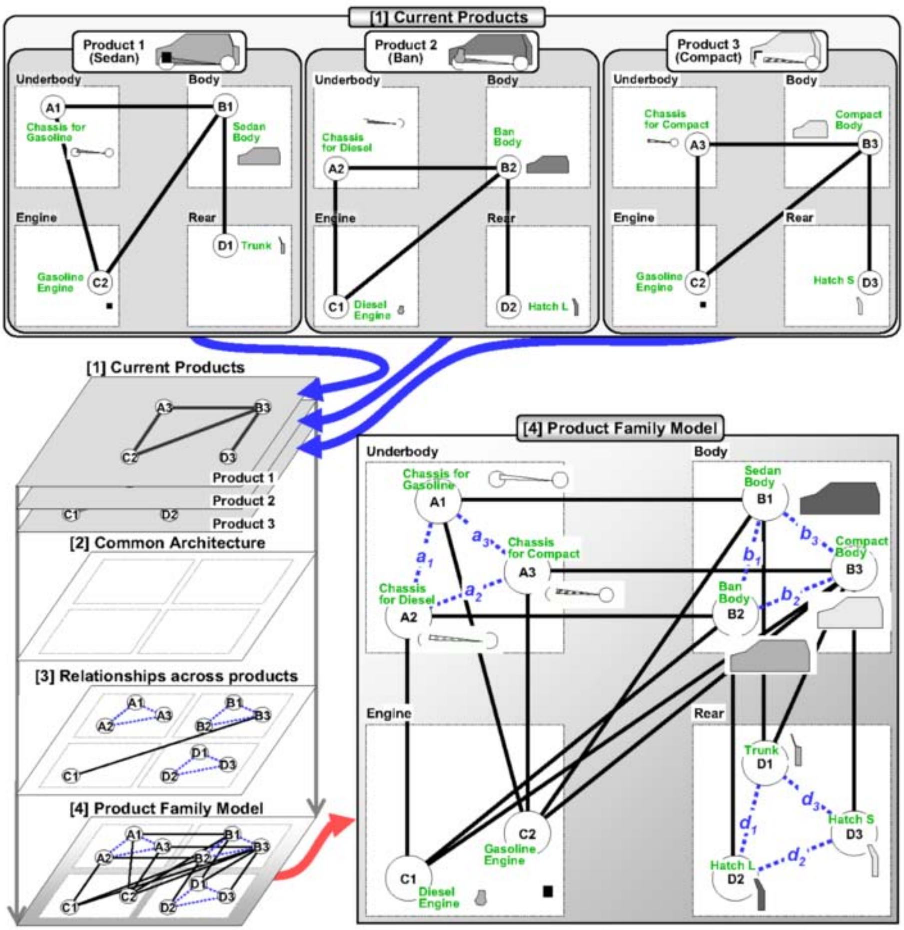

Figure 3 Generation of Product Family Model

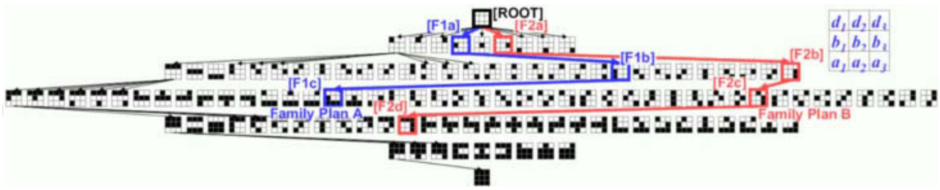

Figure 4 Unification Tree

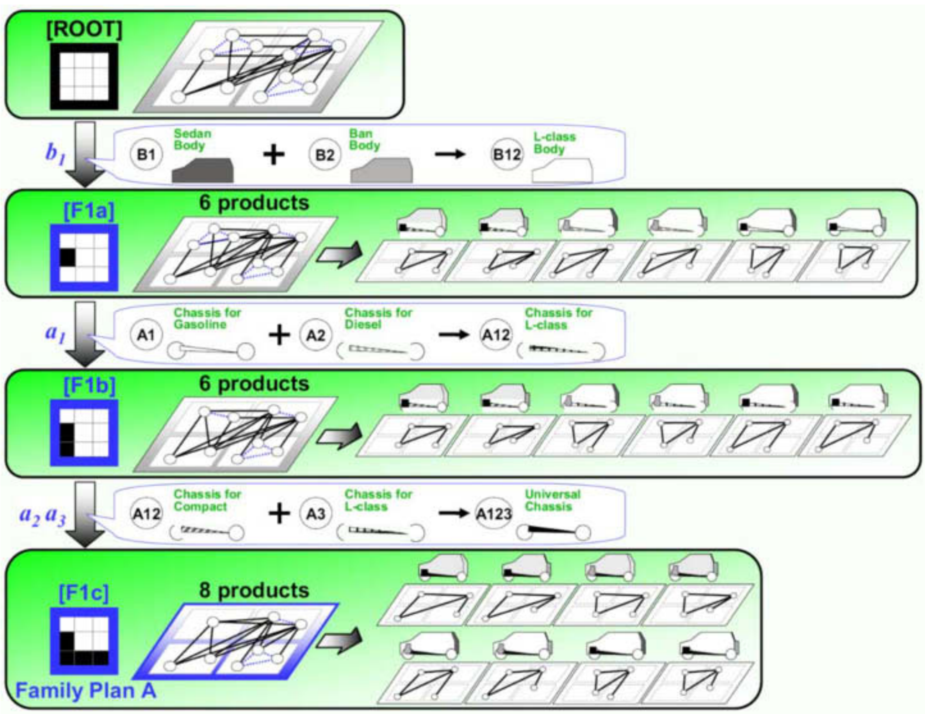

Figure 5 Unification Process of the Family Plan A

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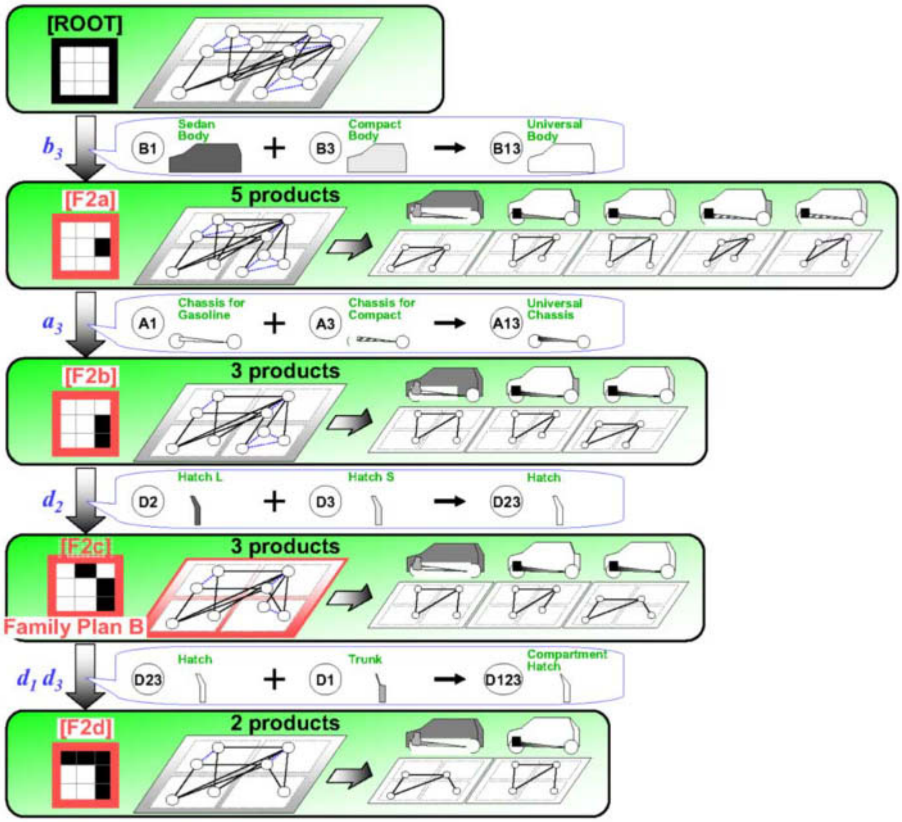

Figure 6 Unification Process of the Family Plan B

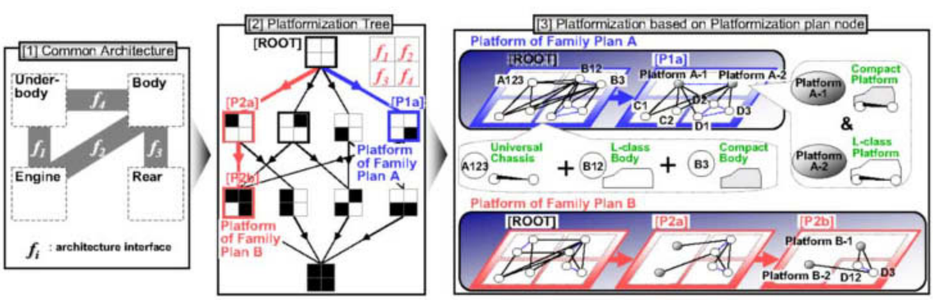

Figure 7 Platformization

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Concurrent Design of a Manufacturing System Utilizing a Microfactory

N. MISHIMA
Fine Manufacturing Group, Advanced Manufacturing Research Institute,
National Institute of Advanced Industrial Science and Technology
Tsukuba, Ibaraki, JAPAN

Abstract: This paper first describes the concept of a microfactory and its design basics. The microfactory is a desktop-type miniature manufacturing system consists of miniature machine tools and manipulators. Since the prototyped microfactory was able to perform the whole process of machining parts and assembling them to a miniature ball bearing, it was able to say that it has a significant capability for micro mechanical fabrication. However, the possibility of the microfactory to improve manufacturing efficiencies of micro mechanical fabrications has not been considered enough. In the paper, the author proposes an evaluation method to calculate efficiencies of the system based on the required time for each process in the abovementioned microfactory project. The paper also tries to propose a concept of concurrent design of the product, manufacturing processes and system configuration, utilizing a microfactory-like system.

Keywords: Microfactory, System configuration, Process planning, Throughput

1. Introduction

Demands for various micro mechanical parts such as for watches, cameras, medical devices is greatly increasing. At the same time, manufacturing systems to fabricate those parts are becoming larger and more complicated. It results a big requirement for energy and space. As a countermeasure for the situation, the author's research group proposed a concept of a microfactory that consists of small machine tools [1] and robots in late 80's. In 1999, AIST developed the first prototype of the microfactory that performs a series of fabrication and assembly on a desktop [2-4]. The microfactory had considerable capability of fabricating and assembling small mechanical parts.

However, one problem for the microfactory is that major applications have not yet found. Abovementioned small parts and products, or medical devices should be good applications. But, since the microfactory had a considerable machining capability, there must be a possibility to replace many micro mechanical fabrication processes. Because of it's safeness, microfactory can be set beside a human operator. Because of it's smallness and lightness, It is also possible to change factory layout according to the manufacturing requirements. If it is possible to show how microfactory can contribute to reconfigurations factory floors, and enhance production throughput, application area of the microfactory will greatly expand. Many other microfactories [5-7] have been proposed until now. And those systems will have great possibilities to improve micro mechanical fabrication processes, as well.

2. Overview of the Microfactory

The features of the microfactory due to extreme compactness of components are predicted as below.
1) Significant reduction of energy consumptions for machine drive and atmosphere.
2) Flexibility in designing the system layout.
3) Improvement of machine robustness against external error sources due to low heat generation and high resonance frequency.
4) Increase of speed and positioning accuracy due to decrease of inertial forces.

The first machining microfactory was prototyped by author's research group in 1999. It was designed to produce miniature metal products on a desktop. A miniature ball bearing was selected as a test product. Fig. 1 shows the overview of the microfactory. Total system and each miniature machines had to be designed to meet some requirements shown below, which are necessary for the test production.
1) Total area of set-up should be no larger than a typical desktop. (60cm X 90cm)
2) The system has to complete every machining and assembly process on the desktop.
3) Steel balls of the ball bearing can be.
4) Each part except the steel ball has to be machined by miniature machine tools.
5) Every part should be handled and assembled by miniature manipulators.
6) Production rates are not questioned.
Fig.2 shows the miniature ball bearing parts and assembly fabricated by the microfactory to show its capability.

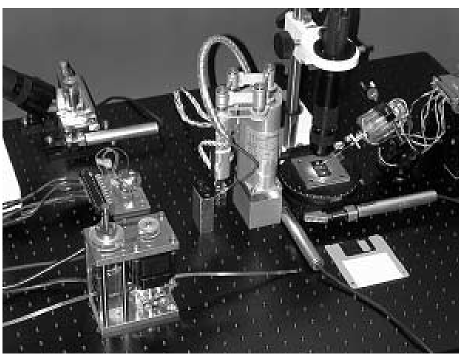

Fig.1 Microfactory

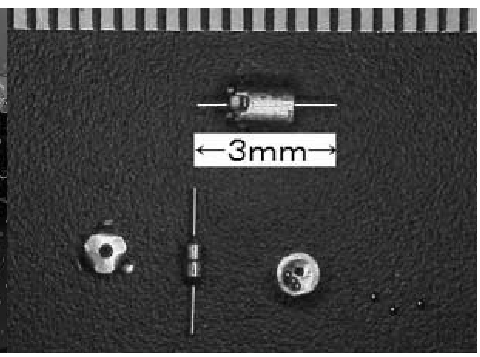

Fig.2 Miniature ball bearing

As the result of the fabrication of the miniature ball bearing, the microfactory was capable to assemble the test product within a desktop, which is approximately 50 by 70cm. In addition, because of its extremely small size, it would be easy to reconfigure the system corresponding to the large variety of the products. Therefore, the microfactory has a future possibility as a manufacturing system to produce many varieties of extra small machine parts. However, it still has some problems, such as the low production rate or the difficulty of the fixture of the product. To apply the microfactory or similar small manufacturing systems to actual productions, those problems have to be solved. Especially to improve the production rate, an appropriate system configuration should be considered. Because of the smallness of each component, it will be easy to add machines to the system to avoid that a

time-consuming process becomes a bottleneck for the overall production rate. In addition, important problems were that really good application for the microfactory had not yet found and there were no theoretical background to support manufacturing system design utilizing the microfactory.

3. Proposal for Process Evaluation of the Microfactory

The microfactory shown in the former section consists of five components. Those are the lathe, the mill, the press machine, the transfer arm and the two-fingered hand. Every component is well-designed and extremely smaller than the corresponding normal-sized machines. Every component has enough capability to machine parts, handle parts or assemble them. To fabricate the miniature ball bearing shown in Fig.2, manufacturing process indicated in Fig.3 was applied. Table 1 indicates the average process time of each process, after the operator had been skilled enough.

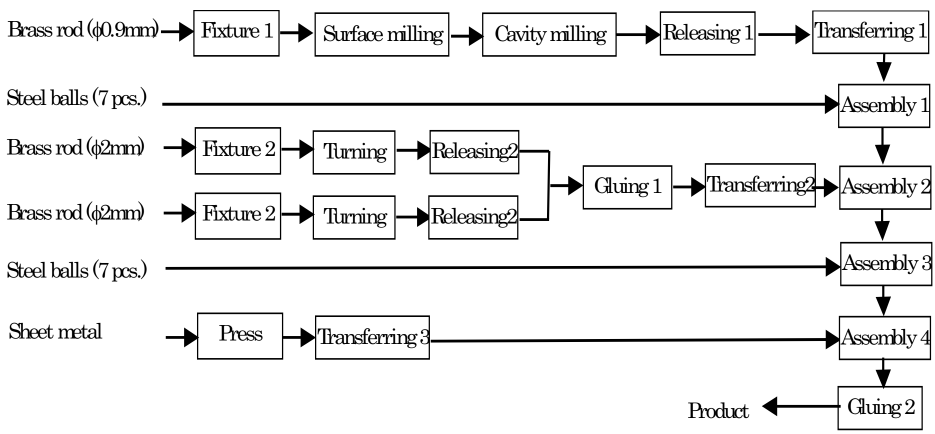

Fig.3 Manufacturing process for the test product

Table 1 Required time and number of operators for each process /unit

Process	Seconds	Operator
Fixture 1	10 sec.	1
Fixture 2	5 sec.	1
Surface milling	1 min.	1
Cavity milling	2 min.	1
Turning	2 min.	1
Press	0.2 sec.	0
Releasing 1	10 sec.	1
Releasing 2	5 sec.	1

Process	Seconds	Operator
Transferring 1	1 sec.	0
Transferring 2	1 sec.	0
Transferring 3	1 sec.	0
Assembly 1	3 min. (per ball)	1
Assembly 2	3 min.	1
Assembly 3	3 min. (per ball)	1
Assembly 4	3 min.	1
Gluing 1	1 min.	1
Gluing 2	2 min.	1

When there are more than two operators, one is for machining processes and the others for assembly, the assembly will be the bottleneck for the system throughput. (While the assembly is ongoing, all the machining processes can be finished.) In this case the average time will be shortened to 50 min, excluding the first unit. On the other hand, initial costs for the machines and labor costs are also critical for manufacturing. Table 2 shows the rough estimation for the initial costs of the machines used in the microfactory. In addition, operator's cost is assumed to be 5.0 (million yen) per person. If the period to consider the system duration is 1 year, the cost per year will be the sum of the machine costs and the labor costs.

Table 2 Machine costs

Machine	Milling	Turning	Press	Arm	Hand
Cost (million Yen)	0.7	1.2	2.0	2.5	5.0

Hereby, the paper defines a coefficient to evaluate the efficiency of manufacturing process; *Ef* by Eq.(1). The index for the original process shown in Fig.3 is 0.00093 – 0.001, depending on the number of operators and machines. Basically, microfactory-like systems are envisioning to change number of machines flexibly according to the required quantity of products. So, the number of machines is not limited to one each. The goal of process planning will be to maximize aforementioned process effectiveness indicator.

$$Ef = \frac{1}{T_p \times (C_m + C_L)} \tag{1}$$

T_p: Total process time in minutes, C_m: Total machine cost, C_L: operator's cost

4. Evaluation of System Configurations

Corresponding to the manufacturing process mentioned in the former section, when the number of operators is not limited, the critical factor is the number of the "Hand." The efficiency is calculated by Eq. (1). When the number of the "Hand" is more than 6, the "Turning" becomes the bottleneck and the indicator is expressed by Eq. (2). However, this value is lower than that of the 5 hands case. Even when the system has 2 lathes and 6 hands, the efficiency is still lower than that of the case having 1 lathe and 5 hands. The results show that having 6 hands won't be useful. If there are 2 lathes, again the bottleneck will be the assembly process and the coefficient is calculated by Eq. (3). Fig.4 shows the behavior of the process efficiency within the range of 12 hands.

$$Ef = \frac{1}{(50/i)\cdot(6.4 + 10i + 5j)} \tag{2}$$

$$Ef = \frac{1}{8.9\cdot(6.4 + 10i + 5j)} \tag{3}$$

$$Ef = \frac{1}{(50/i)\cdot(5.2+10i+5j+1.2k)} \tag{4}$$

Ef: efficiency indicator *i*: number of hands and assembly operators
j: number of machining operators *k*: number of lathes

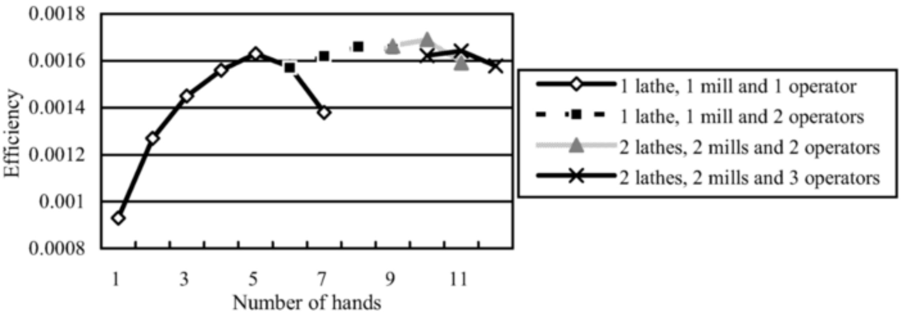

Fig.4 Behavior of the efficiency indicator

Since the "Press" and "Transferring" were not the bottlenecks for the overall throughput at all, the figure shows the behavior of the efficiency indicator due to the change of the number of "Hands", lathes and mills. ("Operators" means number of operators for machining processes.) According to Fig.4, it can be said that there are some local maximums. "5 hands, 1 lathe, 1 mill and 1 operators", "8 hands, 1 lathe, 1 mill and 2 operators" and " 10 hands, 2 lathes, 2 mills and 2 operators" are the local maximums.

Basically, number of machines should be determined by required quantity of the products. But the demands is not always stable. For this reason, it is very significant to consider local maximums and other options for system configuration. For example, in the microfactory case, when the required production rate for the miniature ball bearing is around 10 minutes per unit, the most appropriate system configuration is " 5 hands, 1 lathe, 1mill and 6 operators in total. Even when the required production rate is about 8 minutes per unit, "6 hands, 1 lathe, 1mill and 7 operators" is not the right choice. "7 hands, 1 lathe, 1mill and 9 operators" can be a better system configuration.

5. Optimization of System Configurations According to the Process Change

In the former section, effect of the change of the system configuration has been considered. There are two other strategies to improve efficiencies of manufacturing processes. One is to modify product designs and the other is to optimize manufacturing processes. For the process planning many strategies and tools have been studied. For product designs, DFA tools [8-9] are useful tools to optimize product design according to the assembly difficulty.

However, for the example in this paper, it is difficult to modify the design of the test product independently. The design is too special to apply quantitative analysis

using an existing DFA tool "Assembly" in Fig. 3 was an assembly of micro objects using a master-slave manipulator under a microscopic vision. The process time depended greatly on operator's skill and it was also difficult to replace this process by other easier processes. But, it is still possible to evaluate the efficiency of the manufacturing process by the efficiency indicator in the former section. Qualitatively, it is evident that the bottleneck is the assembly using the two-fingered micro hand. It is difficult to remove the process, because we have not implemented an alternative process of precise micro handling of various shaped micro objects. But it might be possible to modify "Assembly 1" and "Assembly 3" by designing a custom parts feeder to install miniature steel balls in the bearing case. Parts feeders are customized facilities. They are usually less flexible and more productive than robot manipulators. By implementing the parts feeder, the manufacturing process shown in Fig.3 can be modified like Fig.5.

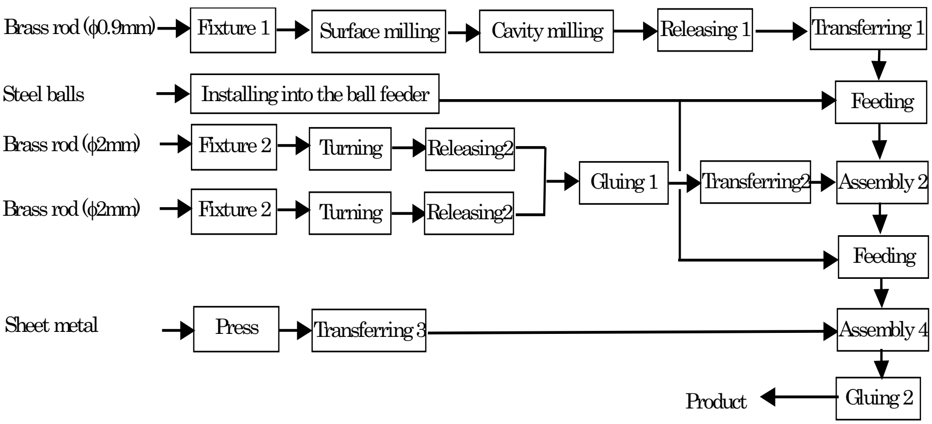

Fig.5 Modified manufacturing process for the test product

The efficiency indicator for the process shown in Fig.5, can be calculated using the same type of equations shown in (2)-(4), considering the bottleneck processes. Unlike the former case, bottleneck process often changes, because the total process time of assembly and machining are relatively close. Therefore, the equation to calculate efficiencies switches frequently. Fig. 6 is the results of the calculation, assuming that the required time for feeding steel balls is 1 minute and machine cost of the parts feeder is 5.0 million yen. Number of the "operators" in the caption of the figure indicates the number for machining operation only. As well as the former cases, the assembly processes need one operator for each hand. Fig.7 is another data arrangement.

Fig.6 shows that the efficiency of the system has been improved. At the same time, the modified systems are more sensitive against the configuration change. The systems having plural lathes and mills are more robust against the deviation of the number of hands. Therefore, when the quantity deviation of the production is small, simple system is preferred. To meet large quantity of production, introduce a few "simple" system is a good strategy. On the other hand, when the deviation range is large, a "complex" system will be better than having a few "simple" systems, in the aspect of system robustness.

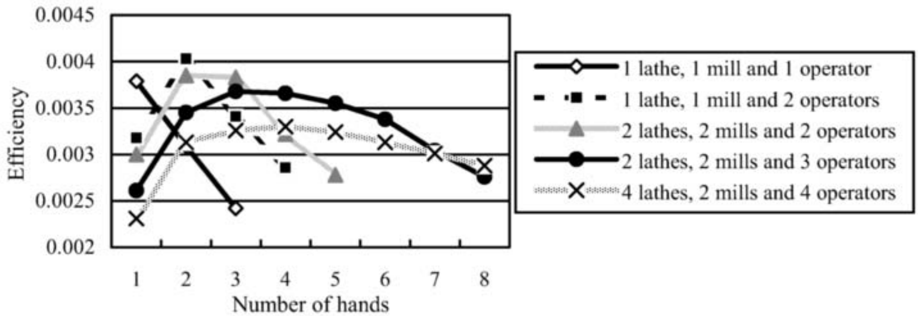

Fig.6 Behaviors of the efficiency indicator for the modified system

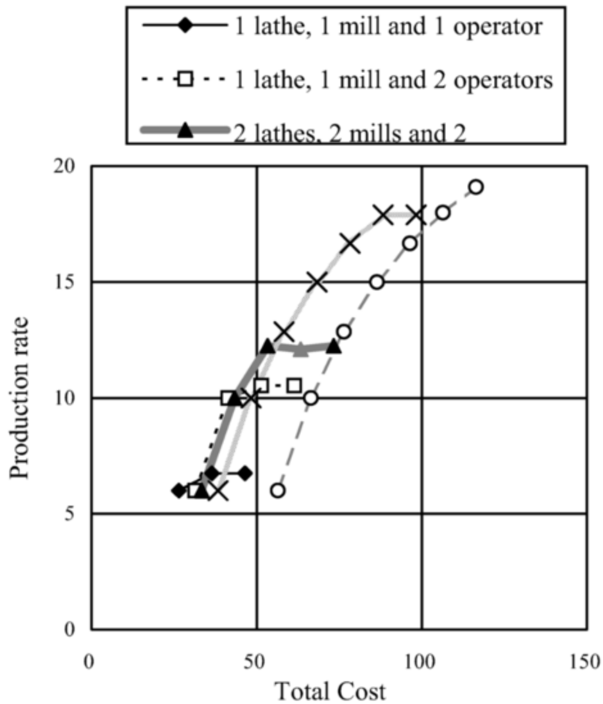

Fig.7 Behaviors of the production rate and costs

Fig.7 shows the relation between the total cost of the system and the production rate. The unit of the total cost is million yen including labor costs and machine costs. The number of products that the system can produce per an hour is used to express production rate. If the design goal is to control total cost below 50 million yen and maximize production rate within the condition, the optimum configuration is “1 lathe, 1 mill, 2 hands and 4 operators in total”. Or, if the goal is to satisfy production rate over

15 per hour and minimize total cost, the answer is “5 hands, 2 lathes, 2 mills and 8 operators”. According to the figure, these types of analyses are also possible.

6. Conclusions

As the result of the test fabrication, the microfactory was capable to assemble the test product in a very limited space. In addition, because of its extremely small size, it would be easy and meaningful to reconfigure the system corresponding to the large variety of the products and production rate.

To prove this point, a simple method to evaluate the system efficiency of the microfactory was proposed. As the results of the analysis, it was able to say that the system had some local maximums. The configuration of the system has to be determined based on the required production rate, system efficiency, costs etc. To optimize the system configuration will be a countermeasure to the low production rate which is a major problem of the microfactory.

Finally, it was suggested that there is a possibility of concurrent design of products, manufacturing processes and manufacturing systems. To maximize the system efficiency, not only the product design, but also the processes and systems can be changed concurrently. Only a microfactory-like system with compactness and human friendliness enable this concurrent design strategy. Therefore, the microfactory has a possibility as a manufacturing system with concurrent reconfiguration capability, to fabricate many varieties of small products.

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Progress Toward and the Promise of Multidiscipline Engine Simulation

Russell W. Claus[1], Thomas Lavelle[1], Cynthia Naiman[1], Ambady Suresh[1], Mark Tuner[2]
[1]NASA Glenn Research Center
[2]University of Cincinnati

Abstract. Current engineering systems tools have limitations that restrict the ability to unite conceptual design and detailed analysis. Numerical Propulsion System Simulator (NPSS) is a multidisciplinary systems analysis tool that has been tackling key concurrent design technology barriers for over a decade. This paper will look at some of the successes achieved by NPSS and areas requiring additional development. NPSS is widely used within industry for full engine simulation of gas turbines and (to a lesser extent) rockets. The first version of this tool has focused on providing an object-oriented framework that provides a sound architecture for both low-and high-fidelity systems models. High-fidelity simulations have just recently been achieved on parallel computers. They demonstrate the promise of this new technology and indicate critical areas for future development.

Keywords: Multidiscipline Analysis, System Simulation, Concurrent Design.

Introduction

The traditional design and analysis procedure for complex, aerospace systems decomposes the system into a series of isolated components and focuses development on each single discipline or component. Consequently, the interactions that naturally occur between components and disciplines can be masked by the limited communication between teams or individuals doing the design and analysis. This can pose serious problems for today's highly integrated propulsion systems, where multidisciplinary issues can adversely impact the overall system performance. Typically, these problems are found late in the design process when early prototypes are tested under realistic operating conditions. If several design-test cycles occur, the new product is usually behind schedule and over-budget.

The Numerical Propulsion System Simulator (NPSS) (ref. 1) was created to address this problem. NPSS is a virtual test cell for propulsion system analysis and design. By harnessing the computing power of both inexpensive computing clusters (ref. 2) and high-performance computing (ref. 3) within an object-oriented software framework (ref. 4), NPSS can analyze a complete engine system at a variety of levels. NPSS has advanced systems analysis through path-finding developments in several critical areas: 1) variable fidelity analysis (or "Zooming") allows the detailed examination of a critical performance element within the engine, 2) object-oriented framework permits the creation of complex software systems, 3) multidisciplinary tools are enhancing detailed analysis of critical components or sub-systems and 4) a user-

friendly run-time environment or Graphical User Interface (GUI) that eases the burden of problem set-up and the analysis of results.

At least one other group (ref. 5) is pursuing this type of simulation and it is instructive to compare the strengths and weaknesses of the approaches used in creating each environment. This paper will review the current state-of-the art in this new field and highlight the progress that has been made. Key development barriers remain and those will be fully reviewed in section 4.

1. NPSS

The multidisciplinary framework of NPSS is illustrated in figure 1. It highlights the three primary characteristics of the simulation environment: coupling, integration and zooming. Coupling refers to the need to perform analysis among all relevant disciplines such as aerodynamics, structures, heat transfer, combustion, controls and materials. Integration involves uniting multiple component simulations into one total system. Finally, zooming enables the individual component simulations to be done at different levels of fidelity within the system simulation.

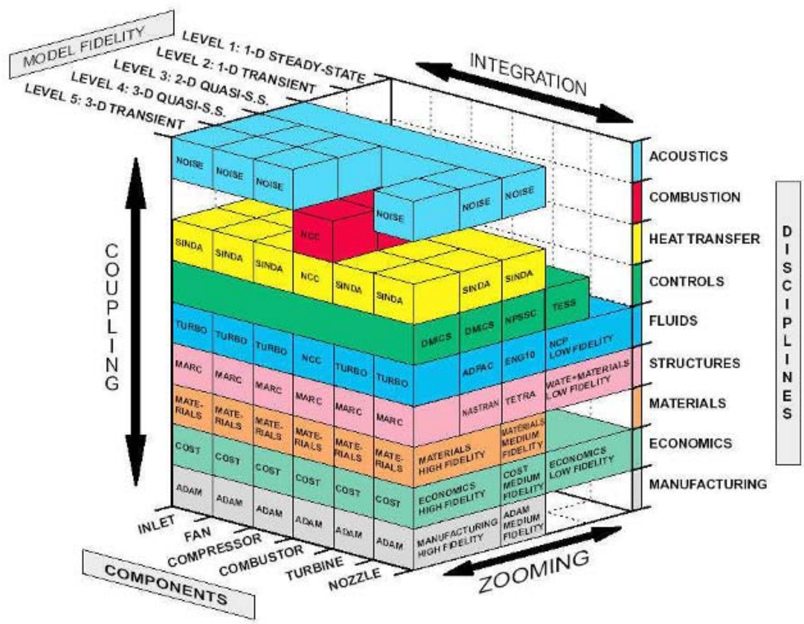

Figure 1. The multi-dimensional representation of the Numerical Propulsion System Simulator.

1.1. Framework

The NPSS framework makes extensive use of object-oriented programming principals. The primary cycle model that uses component maps to capture component behavior (so called zero or one dimension) is written in C++ with a clear modular structure. For calculations requiring distributed / parallel processing, Common Object Request Broker Architecture (CORBA) is used. CORBA (ref. 6) is an object-oriented framework that uses Interface Definition Language (IDL) to define clear interface(s) between remote or local objects. It is typically used to unite a complete system simulation (low computational demand) with a more detailed simulation of a single component or sub-system that uses extensive computing resources.

In this manner, the NPSS framework is simply a data-flow network that can be used to perform system analysis (time-accurate or steady-state) on any system comprised of a number of sub-system models. For example, this framework has been used to model the time-accurate blood flow within a human arterial system (ref.7).

1.2. Multiple Level Analysis

NPSS uses five discrete levels of analysis. Level 1 uses 0 dimensional performance maps to represent component behavior. Each component, in turn, is composed of a series of complex flow paths and individual parts, but these are all grouped into one performance representation. Level 2 expands upon level 1 through the inclusion of transient models loosely based on actual geometry to establish mixing volumes for a transient simulation. Level 3 describes an axisymetric representation of system components. This level is closely related to the flowpath geometry but lacks actual three-dimensional information. Level 4 introduces the three-dimensional geometry for steady-state simulation with Level 5 adding time-dependant complexity. A zooming analysis might bridge any of these levels of simulation, but the common approach is to perform a detailed Level 4 analysis of a part of one component with a Level 1 system model providing boundary conditions for the higher fidelity analysis. Note that the actual higher fidelity methodology and coding is not currently part of the NPSS software distribution; NPSS simply provides the framework to allow the link between itself and any user-supplied higher-order codes. Zooming techniques have been explored but not developed for general component / system analysis.

1.3. Zooming for detailed analysis

At the conceptual level, a zooming analysis seems straightforward. Associated with the component under consideration are performance and state variables such as pressures, temperatures, and massflows; these values are input into more detailed analyses to validate or modify component performance. Transforming one-dimensional flow field data into a three-dimensional flow condition and vice versa may be required depending on the zooming analysis. Schemes that conserve mass and energy have been studied with success (ref.8). The challenge comes from multiple sources: detailed analyses require more analysis time than simplified Level 1 or 2 models, each analysis is expected to produce slightly different results that follow a feedback loop to alter the specified inflow conditions, a subcomponent within a component map may require

extensive modeling to yield inter-component state variables, and finally there is no guarantee that the "stiffness" imposed by a new detailed analysis will permit the system to reach a converged state.

NPSS can use a number of computational techniques to couple different computer analyses. First, a system call can be made to integrate with an external application. This approach is useful for integration with significantly different computational frameworks, but it can impose a significant computational delay. Second, external applications can be integrated using CORBA calls. This is useful for distributed applications such as high-fidelity, detailed analysis that might be run on a parallel processor. A third technique is commonly used when the external application does not impose a significant computational burden and can be executed on a single processor. A Dynamic Linked Module (DLM) efficiently links external applications as a shared library, but must be compiled and be local to the single computational processor.

The fundamental assumption behind zooming is that a more detailed analysis will provide a better representation of one part of the overall system model. This detailed analysis almost always requires more inputs and also produces more outputs than the lower level analysis it is supplementing. One important part of zooming is to take the appropriate data from the low fidelity analysis, augment it with additional information required to run a more detailed analysis, and then extract the appropriate data out and return it to the low fidelity model. It is important to note that the goal here is not to create a model of models that is controlled by one engineer. The goal is to create a model that is shared by the different discipline experts. As it is being exercised, it is the joint responsibility of the different experts to interpret and validate the results.

It is also important to note that the goal is not to link codes together at the systems level. The goal is to link models. A code is a general analysis tool that can be used over a wide range of designs. A model is a specific implementation of a code that an expert only allows to be varied in a predefined way. It is not possible to link a cycle analysis code with a meanline compressor code in a general way. However, it is possible to integrate a high bypass turbofan simulation with a ten stage high pressure compressor meanline model. In this case, the compressor meanline model will be wrapped. By wrapped, we mean designing it so it will take cycle values of incoming temperature, pressure, and shaft speed and using them, along with expert inputs, to determine the compressor operating conditions that are fed back to the overall model. The wrapping process greatly restricts the number of inputs and the amount these values are allowed to change.

Another factor to take into consideration is the time required to execute the more detailed analysis. Some CFD codes require many hours to run one pass. Since an engine analysis can sometimes require several hundred individual passes to balance, numerical techniques must be developed to cut down on the number of times the detailed codes are required to run.

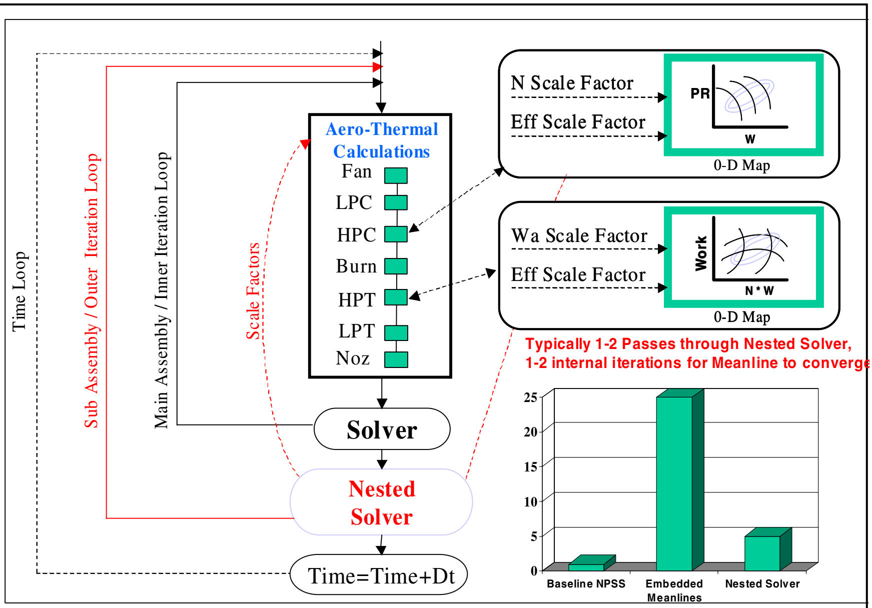

Figure 2. Nested solver usage within the NPSS framework.

The example in figure 2 shows one way the nested solver approach within NPSS is used to include higher fidelity analysis in the design space while keeping the number of high fidelity runs at a minimum. The technique is straight forward and is similar to the data reductions that are used to match a cycle simulation to test data. First, the low fidelity model is run to convergence. Then, the outputs from the low fidelity code are used as boundary conditions for the higher fidelity analysis. The high fidelity models are then run. The high fidelity output is then considered to be more accurate than the lower fidelity models. The results from the high fidelity codes are then treated as demand values used to tune the low fidelity analysis. In this example, map scalars are varied until the map based component performance matches the higher fidelity prediction. The result is new low fidelity results that are then used as new boundary conditions for the high fidelity model. The overall process is repeated until an overall convergence is reached and the models are all consistent.

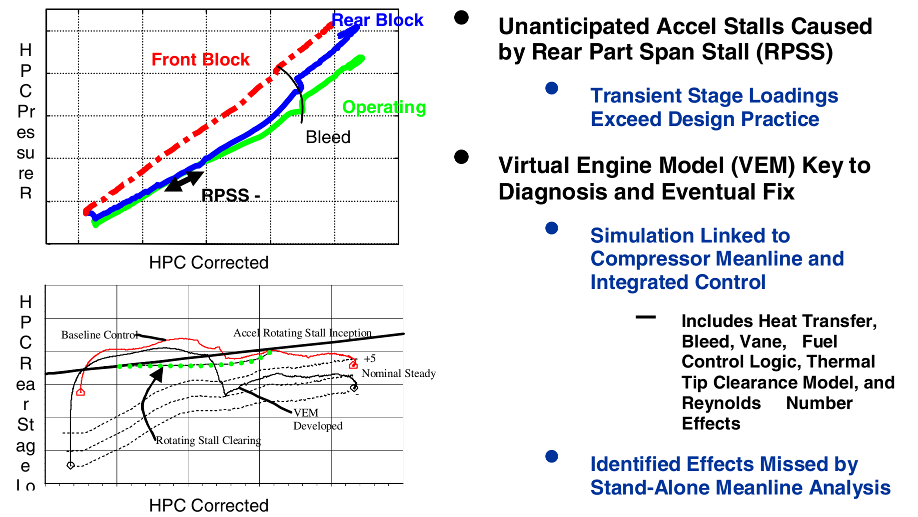

Figure 3. NPSS zooming example to address a stall problem.

A real world example of this technique is shown in figure 3. A gas turbine engine manufacturer was having a stall problem with one of their development engines. Creating an integrated model was key to fixing the problem. The cycle group had a model of the overall system. The compressor designers had a meanline model of the high pressure compressor this model was wrapped and integrated within the cycle model. By wrapped we mean designing it to take the high level model values of incoming pressure, temperature and shaft speed and use them, along with other expert inputs, to determine the compressor performance. The output from the meanline code is then used to determine scale factors on the low level model (0 D). The two models were integrated using the method listed above. The model was run jointly by the two groups. The integrated models identified a real part span stall that was being missed by stand alone analysis. The problem was fixed by redesigning the control. Identifying the problem and fixing it enabled the company to save substantial resources.

1.4. Analysis Code Coupling

The typical development of detailed analysis has been focused on single discipline technology development. A propulsion system has inherent multi-disciplinary problems, for example - aero-elastic blade response, but many sub-systems are weakly coupled. For these sub-systems a relaxed form of coupling can be applied. These so-called “relaxed-forms” of coupling can be iteratively coupled through periodic boundary condition updates. However, even this “relaxed form” of coupling involves many complex issues. First, there is the development of techniques to transfer computational quantities (physical representations) between different analyses with varying time and

space scales. A common example of this type of problem would involve structural and aerodynamic coupling that occurs with aero-elastic structures. The structural analysis might commonly be performed in a modal domain while aerodynamic variables are represented in three (or four)-dimensional space. Second, while all high resolution analysis requires an accurate representation of the geometry and appropriate boundaries, they may not use the "same" geometry. A structural analysis has a completely different view of a gas turbine engine that an aerodynamic flow-path analysis. Finally, transferring data between codes of similar time and space scales requires careful consideration of the properties that are transferred. Extensive interpolation and averaging can impose a significant computational burden. Strong conservation of the primitive state variables is desirable, but the benefits versus costs of such an approach are usually unclear.

Any analysis code coupling must ensure a seamless and consistent solution throughout the combined flow domain with accuracy comparable to a single code simulation. To achieve this objective, two possible approaches have been used.

In the first approach, the solution from one code is used to supply boundary conditions for the other code. For example, at a subsonic interface, the upstream code supplies total pressure and total temperature to the downstream code while the downstream code supplies a static pressure to the upstream code. While this approach is easy to implement and requires no code modifications, it has the following disadvantages:

1) the procedure may change depending on the interface conditions (supersonic-subsonic),
2) generally works only for steady state solutions,
3) there may be some loss of accuracy at the interface.

This method has been successfully used to couple fluid codes to thermal and structural codes (ref. 9). In addition, this is the only method possible when the source code is inaccessible.

A second approach, used to couple codes of the same discipline, is to mimic the inter-block data transfer within a multi-block code. Here, typically, ghost cells are introduced at the code interface boundary so that the boundary cells can be updated just as if they were interior cells. These ghost cells are then filled with values from the other solver. This approach has the advantage that the coupling procedure is valid for all flow conditions at the interface and is also equally valid for unsteady or steady flows. This approach is illustrated in the figure 4 where two codes are assumed to be cell centered codes with a five point stencil.

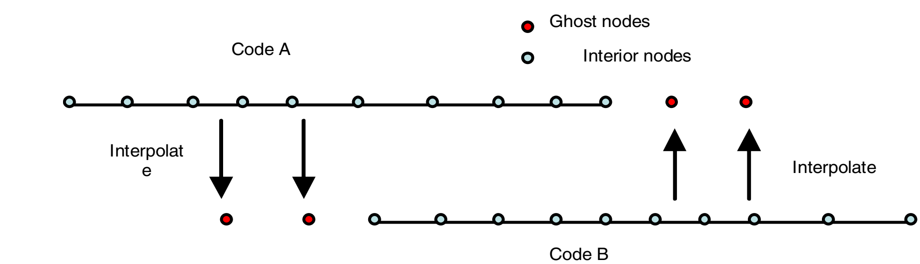

Figure 4. Code coupling procedure based on mimicking the multi-block data exchange.

This approach is usually implemented with the data exchange taking place every time step, but if necessary it can be implemented with the exchange taking place at finer levels such as at every Runge-Kutta stage or every sub-iteration etc.

With unsteady simulations, another issue is the synchronization of the various solvers which is required to preserve time accuracy. The simplest approach consists of running the simulation at the smallest of the time steps of each solver and exchanging data every time step. The solvers are modified to advance in time lockstep usually through MPI calls or other I/O. When there are very disparate time steps, this method is not feasible and some other method, perhaps involving an interpolation in time becomes necessary.

The data exchange taking place between coupled solvers usually involves some form of interpolation and translation. Interpolation is generally required because the nodes of the target solver do not coincide with the nodes of the source solver. To facilitate interpolation the two solvers can meet at a common interface or have a sizeable volume overlap. With curved boundaries and coarse grids, slight extrapolation is unavoidable as figure 5 illustrates.

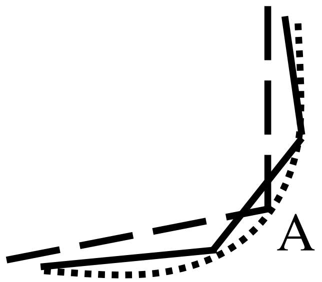

Figure 5. Interpolation between two discrete grids (solid and dashed lines) fails at point A on a curved boundary.

Once the source codes variables have been interpolated to the target code locations, they have to be translated to the target code's needs. This usually involves a transformation of the interpolated variables to correct for different units, different solution variables, different non-dimensionalizations in the target code. These difficulties of translation, while not severe, may be greatly aided by the definition of a universal interface standard that defines what data are exchanged between codes and in what format. With such a standard in place, code developers can use this standard to define a code coupling boundary condition in which the translation from the standard to the code's requirements is accomplished. Two codes with such a boundary condition have no translation issues and are thus easy to couple.

1.5. Applications

NPSS uses a wide variety of Computational Fluid Dynamics (CFD) analyses. The primary tool for turbomachinery is the APNASA code, ref. 10. This software calculates multistage turbomachinery flow fields by modeling inter-blade influences through deterministic stress terms. This model substantially reduces computing requirements over a time-accurate analysis and allows finite computing resources to be spread among other engine components.

The combustor is modeled using the National Combustor Code (NCC), ref. 11. This analysis uses an unstructured mesh to capture the complex flow geometry common to modern gas turbine combustors. The software is designed for parallel computation and employs a standard κ- ε turbulence model with various combustion models.

For time-accurate turbomachinery calculations, NPSS employs the MSU TURBO code, ref. 12. This permits a direct calculation of multistage turbomachinery without simplifying models, however, it does impose a significantly larger computational, especially for full-annulus configurations.

The WIND code, ref.13, is used for inlet or nozzle flow geometries. This software is the result of a government / industry collaboration to provide a validated, general purpose flow code for three-dimensional geometries. WIND was written to calculate compressible fluid flow with a multi-zone structured and unstructured mesh and several turbulence models.

1.6. Software Management and Development

Through a Space Act Agreement and NASA Industry Cooperative Effort (NICE), three levels of teaming combined with a formal software development process enabled involvement of NASA, industry, and DOD from planning through development and implementation. The NPSS team consists of propulsion experts and software engineers from General Electric Aircraft Engines (GEAE), Pratt & Whitney (P&W), The Boeing Company, Honeywell, Rolls-Royce Corporation (RRC), Williams International (WI), Teledyne Ryan Aeronautical, Arnold Engineering Development Center (AEDC), Wright Patterson Air Force Base (WPAFB), and NASA Glenn Research Center. The NPSS activity is a catalyst for establishing new standards for interfacing with tools of different disciplines and a forum to share best practices among competitors. Teaming with the users throughout the development process and providing incremental releases, results in detecting problems earlier, accelerating development, and increasing the probability of product acceptance. The standardization across the US government and industry facilitates collaboration in support of current and future NASA missions.

The primary object-oriented analysis and design technique used on the initial development on NPSS was a very informal approach to a combination of Jacobson, Rumbaugh, and Booch, before the Unified Method was officially defined. There is no enforcement of required diagrams. Use cases are drafted with the assistance of partners, which provided a good starting point. Object models and interaction diagrams are developed for new major functionalities, but are not required on all requirements, enhancements, or defects. Also, as capabilities are changed, it is not mandated that the diagrams be updated. The analysis and design documents are drafted to get started and are used as vehicles to progress to the next step. The focus remains on having a deliverable product with updated documentation for every change request on a daily basis.

The NPSS incremental release process is based on the evolutionary delivery life cycle model which is considered a “best practice” in software engineering. It provides its rapid development benefit by delivering selected portions of the software earlier than would otherwise be possible. This lifecycle model provides some ability to address changing requirements and improves progress visibility. NPSS Software requirements are documented, approved with signature by partners, and revisited for

each full version release. The formal reviews are conducted for requirements and acceptance, only. The analysis and design reviews are replaced by frequent inspections and peer reviews. Analysis and design documentation is recommended but not required for all changes. Updated user documentation is required when any change is incorporated. Thorough regression testing and software configuration management is conducted per every change request merged. Good team dynamics, team communication, and dedicated developers are key ingredients in producing an accepted product. Following software engineering best practices contribute to a successful and accepted product. Practices such as the following are used: top ten risks, incremental development, flexible scheduling when possible, user involvement throughout the process, postmortem analysis sessions, continuous process improvement, daily builds, and rigorous regression test suite. After the basic architecture was in place, a working product has always been available for the user to test the latest capabilities.

2. NPSS Full High-Fidelity Simulations

The first high-fidelity compete gas turbine simulation was recently demonstrated (ref. 14) using a GE90 engine for experimental validation. This simulation made extensive use of APNASA, NCC and other flow analyses. Results were both benchmarked with the engine cycle deck and new component maps were included into the cycle based on the high-fidelity calculations. Figure 6 displays a visualization of a only one-half of the complete engine simulation. Local pressure is used to color the flow path.

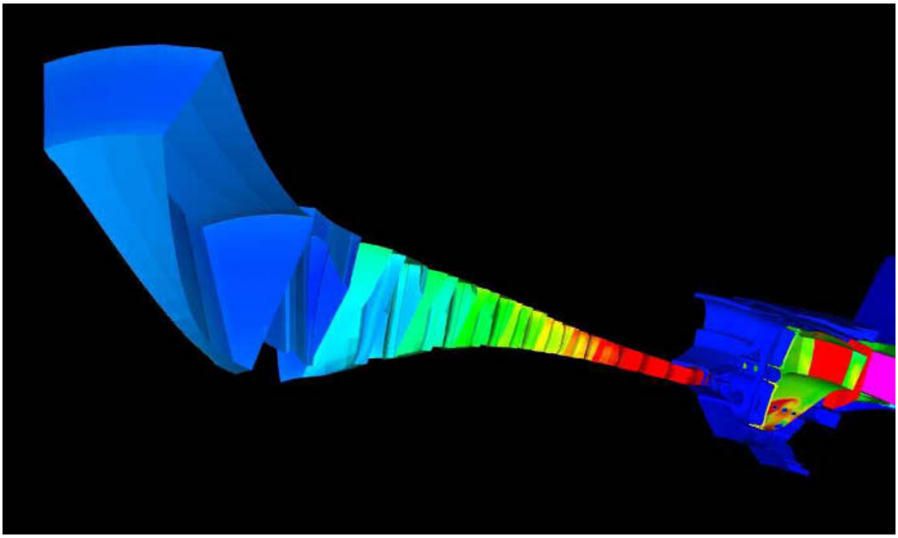

Figure 6. Visualization of the High pressure compression system and combustor for the GE 90 simulation.

Operating characteristics of the high-fidelity, 3D component models were integrated into a cycle model via partial performance maps generated from the CFD flow solutions using one dimensional meanline-turbomachinery programs. These operating characteristics were so called "mini-maps" due to the narrow operating range

that was simulated using the high-fidelity models. Results that compare the experimentally validated cycle data with the high-fidelity models results are shown in table 1.

	Wc (rel diff)	PR (rel diff)	TR (rel diff)	Efficiency (% diff)	Nc (rel diff)
Fan	0.71%	0.45%	-0.17%	2.32%	1.09%
Booster	0.08%	-0.60%	0.08%	-1.37%	1.09%
HPC	0.75%	-0.49%	0.05%	-0.29%	0.97%
HPT	1.21%	-3.52%	0.06%	1.79%	0.99%
LPT	-2.34%	2.35%	-0.22%	-1.54%	1.00%

Table 1. Variance between an experimentally validated cycle model of the GE 90 and the results of a high-fidelity simulation.

The variations in table 1 result in predicted Specific Fuel Consumption (SFC) that is 0.99% lower than the experimentally validated number and a 0.99% higher thrust level. This implies that the high fidelity simulation is approximately 1% more efficient (in terms of fuel efficiency) than the actual hardware. This number is approximately 4 times greater than the expected engine-to-engine variation.

Another example was done with a rocket engines simulation. In this case, a the pump calculations in a lumped parameter simulation were augmented with CFD analysis of on of the pump stages. The model was run then to convergence. The converged values were used as boundary conditions for the pump CFD. The CFD was then run and the results were used to apply adjustments to the maps in the manner described above. There is one important factor to keep in mind. Because the CFD execution is done after the cycle is converged, any number of components can be added to this model without slowing the overall process, if distributed computing is used effectively

3. Other Research Efforts

The Stanford Advanced Strategic Computing (ASC) Initiative, ref. 5, has a goal of analyzing a complete, time-accurate gas turbine engine. They have estimated that this goal may require on the order of 10 million CPU hours on today's fastest computers. For this reason they had to approximate the geometry to reach achievable computing times. Several simplifying models have been used including:

a. Only a partial sector of the turbomachinery is analyzed resulting in a airfoil shape change to maintain solidity – a 20 degree sector is used.
b. Tip gap regions are neglected.
c. Secondary flows are neglected.

These limitations restrict the potential value of the simulations. Issues such as blade-to-blade interactions may be explored and simplifying models developed using these numerical-experiments, however the system calculation cannot be directly compared with experimental data. The actual geometry used follows the design of an existing gas turbine, but by neglecting tip clearance, secondary flows and the full annulus, the simulation will not currently permit comparison with engine data.

Despite its limitations, ASC project is an excellent start toward a complete engine simulation. It has developed sophisticated software tools enabling calculations on massively parallel architectures (ref.5).

4. Development Needs

The NPSS research conducted over the past decade has highlighted several areas in need of additional technology development including:

a. Secondary flow modeling beyond current source / sinks – The secondary flows can involve as much as approximately 20-30% of the core massflow. NPSS currently models these flows as a series of sources or sinks in the detailed analysis, APNASA. This ignores significant flow phenomenon such as film cooling. This may account for the performance variation seen in section 2.
b. Time-dependant MultiStage turbomachinery – Time accurate turbomachinery simulations may be needed to address phenomenon such as stall. It may also better resolve the physics of new-technology compressors.
c. Inclusion of turbine blade film cooling models with real gas – Most current gas turbine engines use film cooling in the turbine section of the engine. The physics associated with these “small-scale” features are extremely complex and may require new types of models to capture both heat transfer and flow loss information. Although the data to validate such models does not involve real-gas effects, the practical application requires real-gas treatment.
d. Guidelines / models for the integration of time-accurate and steady-state codes – Some components of a gas turbine engine are more readily modeled using time-accurate simulations, but other components may be sufficiently modeled using steady-state models. Techniques for integration of these calculations are needed.
e. Grid construction and easy modification (parametric basis) – A turbomachinery blade can be represented in a finite number of parametric variables. To rapidly assess new designs and concepts, an efficient set-of-tools that allows a quick-set-up of detailed analysis grids from parametric changes would be highly beneficial.
f. Assessment of analysis limitations at all levels (0 to 4 D) – All components of a gas turbine engine can be analyzed at several different

levels of fidelity. A clear enumeration of computational costs versus predictive accuracy is needed for the full range of component operation.

This extensive list of NPSS development needs is not intended to be all inclusive. Rather it highlights areas of current focus and will doubtless expand and contract as future research is completed. The critical factor is to ground these developments with experimental development of new engine systems.

5. Concluding Remarks

Multidisciplinary systems analysis is rapidly becoming a practical tool for the most complex aerospace systems. However, the approach undertaken must be strongly grounded in practical application with a close validation through full system experiments. NPSS has been developed following such a process and is currently supporting a large industrial / university community. Yet, its great potential has just recently begun to be realized. With the inclusion of new techniques prototyped by the ASC project at Stanford, the promise of an advanced virtual wind tunnel for complex engine systems is tangibly close.

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Intelligent Layout Design for Complex Mechatronic Products Based on Distributed Knowledge

Caihong WANG, Jianzhong CHA, Yiping LU, Wei LIU and Gang LI
Beijing Jiaotong University, Beijing, China

Abstract. As complex product layout problems are difficult to be solved with simplex optimum algorithms, an approach is introduced to implement intelligent human-computer interactive layout design system based on distributed knowledge for complex mechatronic products. A web-based system structure is represented also, which combines the merit of C/S and B/S. The layout design knowledge of complex products is divided into parts knowledge, space knowledge, layout case, rule knowledge and constraint knowledge. A compound knowledge model is set up by object oriented method, and data structure is described by array. This knowledge representation method makes the maintenance of knowledge base much easy.

Keywords. Layout, distributed knowledge, compound model, knowledge based system

1 Introduction

Packing problems [1, 2, 3] are encountered in many industries, especially for complex mechatronic products, such as tank, aircraft, shipbuilding and high speed train. The aim of such problems is to obtain less space and weight, so all parts need to be packed in limited space carefully. There are many optimum algorithms, such as accurate algorithm [4], genetic algorithm [5, 6], simulated annealing [7] and extended pattern search algorithm [8], hybrid algorithm, expert system [9], Virtual Reality[10] etc. used for solving this kind of problems. Accurate algorithm is effective in solving some specific packing problems. Heuristic algorithm is one of the accurate algorithm, but it is very difficult to gain heuristic rule for irregular objects or the packing problem that optimum objective is not space utility. Meta heuristic algorithm is fit for the packing problem with large scale. Hybrid algorithm searches in space by stochastic method and reduces search space by heuristic rule or knowledge based method.

The modeling and computing complexity of complex product packing problem is obvious. Its layout result resolved by single algorithm is usually not better than by human with rich layout experience. The reason is that layout knowledge includes process knowledge, experience knowledge, instance knowledge, constraint knowledge and etc. Diversity of layout knowledge makes the layout result more difficult to solve by the single optimal algorithm, and that needs the more diversity of problem solving methods. AS knowledge is usually distributed in different environment, designer must search and select design knowledge in the distributed network resource during their

product layout design. So, this paper presented the intelligent layout design system based on distributed knowledge to solve this kind of problems.

2 Framework of intelligent layout DESIGN SYSTEM

Figure 1 shows the framework of the human-computer interactive packing design intelligent system based on distributed knowledge for complex mechatronic products. This structure realized interior management and exterior net server. Administrator and authorized interior users can visit meta-system by LAN (Local Area Network). Exterior user can visit WEB server via internet, then the meta-system by WEB server. The structure combines the merit of C/S and B/S. Exterior users can query information by the computer connected to internet, and do not need other complicated equipments. The virtue of the mixed structure is that exterior users have no authority to visit meta-system server directly, which insures the safety of databases. Interior users have strong association with question base, knowledge base, database and graphics base. The mixed structure makes query faster than B/S or C/S structure. Knowledge base, database, graphics and subsystems base can be installed in same computer, or different computers with meta system.

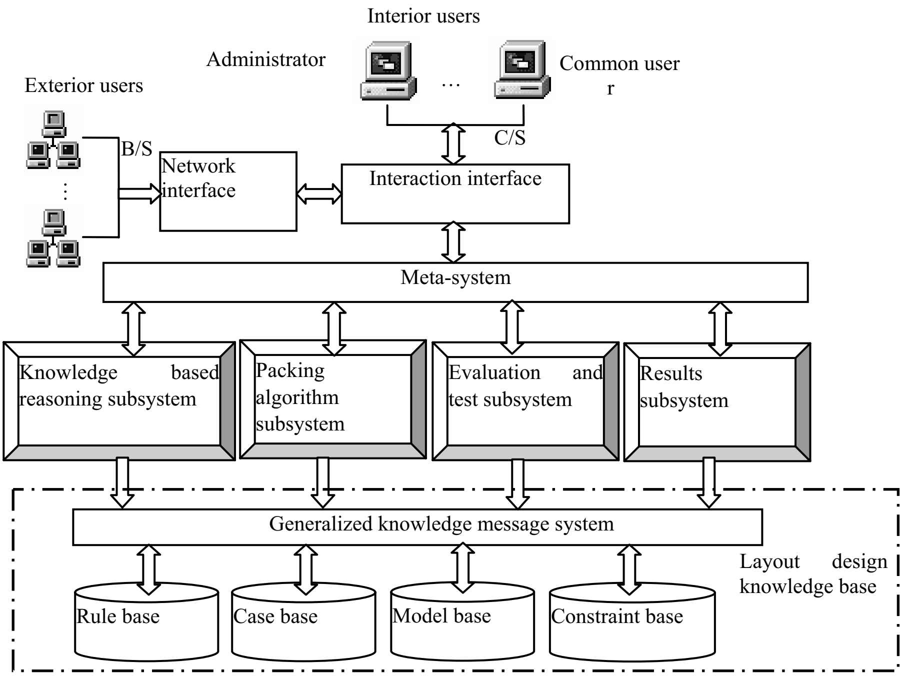


Figure 1. Framework for intelligent layout design system

(1) Meta system manages other subsystems, database, knowledge base and graphics base. Firstly, meta system analyzes and plans design requirements or target, then assigns tasks to corresponding module. Meta system makes knowledge and information communication as well as share them in subsystems.

(2) Knowledge-based reasoning (KBR) subsystem converts user's requirements and relationships of parts to constraints, and then arranges parts according to the constraints. This packing result is an initial one and may not be excellent.

(3) Packing algorithm subsystem gets best optimum packing result that satisfies all constraints. In this subsystem, user can adjust position of parts when not satisfied with packing result. Packing result will be sent to evaluation and test subsystem. As the dificulty of packing three dimensional entities, original packing objects should be simplified during packing procedure. The simplified objects will be packed through the human-computer interactive packing algorithm, so that the packing result of parts in power cabin can reach optimum after fulfilling capacity constraints and location ones. At the end, the simplified parts will be restituted to their original 3D shapes by results subsystem.

(4) Evaluation and test subsystem evaluates modules and packing results according to performances (such as thermodynamic performance and hydrodynamics one etc.) and other constraints. If a performance is not satisfied, parts will be repacked or redesigned and then the satisfied results will be outputted by theresults subsystem.

(5) Results subsystem visualizes the design results on a commercial CAD system (Pro/Engineering) and outputs their results to documents.

(6) Generalized knowledge management system provides users with the function of modify, extend, delete, search, query. Distributed knowledge base is independent of the intelligent layout design system, which makes it easy to modify and maintain knowledge base and improve performance of whole system.

At first, according to users' requirements, meta-system arranges tasks to knowledge-based reasoning system. Then, primary packing scheme can be gained by the knowledge-based reasoning system. Furthermore, these results are sent to evaluation and test subsystem to be evaluated. There are three types evaluation results obtained from this subsystem: (1) If the evaluation result satisfied, the result and its graphics can be added to case base and outputted. (2) If the evaluation result dissatisfied with parts packing positions, the result can be send to packing algorithm subsystem. The subsystem will layout through human-machine cooperative method. (3) If the evaluation result is dissatisfied with parts types, the type of some parts needs to be chosen or designed again.

3 Layout design knowledge module

Layout design knowledge includes declarative knowledge (object knowledge), heuristic knowledge (layout rule), experience knowledge (from experts), instance knowledge (layout case) and uncertain knowledge and so on. Simple local problems can be solved by simple domain knowledge, but complex problems can only be solved by multi-domain knowledge. Knowledge Integration is the core of intelligent layout design system.

According to its application, the knowledge is divided into layout case, rule knowledge, constraint knowledge, as shown in figure 2. Layout case includes layout object knowledge, layout space knowledge and power-cabin design case. Layout object knowledge describes for performance and structure of parts. Layout space knowledge describes the shapes of power-cabin. Power-cabin design case describes the performance of power-cabin and the position of parts. Rule knowledge includes knowledge of choosing parts and heuristic rule of layout. Constraint knowledge is

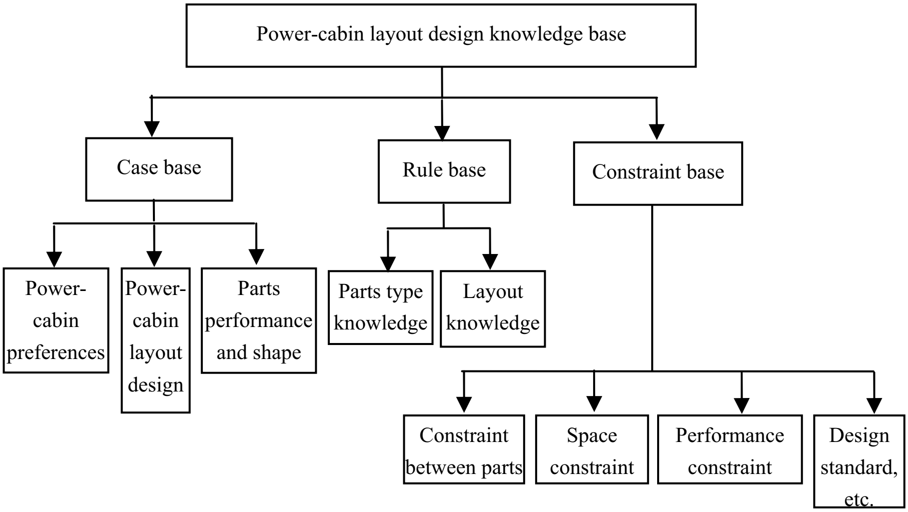


Figure 2. Category of layout knowledge

composed of parts position constraint, performance constraint and national standard, etc.

4 Knowledge representation and reasoning

Knowledge representation methods include first-order logic, frame, semantic networks, object-oriented, agent, rough set theory and so on. In this paper, all knowledge is expressed with object-oriented method.

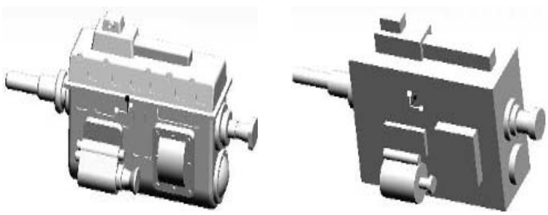
4.1 Layout case

(1) Layout objects knowledge

As packing algorithm can only deal with simplified objects, the simplification of objects is very important. Complex objects can be simplified as circles, rectangles or cylinders by secondary development of CAD software [11]. Bintree or octree [12] was introduced for simplifying irregular objects. The simplification transfers 3-D packing problem to 2-D packing one. In this system, complex objects are simplified as the combination of cuboids and cylinders, as shown in figure 3. Layout objects knowledge includes performance knowledge and shape knowledge.

Performance knowledge

```
class Cengperformance
{
    public:
    char position; //position, engine.dbs
    double unitpower; // unit power (kW/t): 15
    double power; // power (kw): 544
    double rev;  // rev (r/min): 2200
```



3.1 Before simplified 3.2 After simplified

Figure 3. Simplified shape

```
    ……
}
Shape knowledge
AxInfo//position, posture, base point (x,y,z), rotate angle //(alpha, beta, gamma)
 {
    Double x;   Double y;          Double z;
    Double A;   Double B;          Double G;
}
SInfo    //shape information
{
    Double x1; Double x2;
     Double y; Double z ;
}
```

Table 1. Parameters' meaning of primitives

Parameter	Rectangular	Trapezia	Cylinder	Frustum of a cone	Sphere
x1	length	Legth1	radius	Radius1	radius
x2	—	Lenth2	—	—	—
y	width	width	Y=X	Radius2	—
z	height	height	height	height	—

As cuboid x1, y and z represent length, width and height of rectangle respectively, x2 should be null. As trapezia, x1, x2, y and z represent lengths of two edges, width and height. As cylinder, x1 and z represent radius and width respectively, x2 should be null, and y equals x. As frustum of a cone x1, y and z represent two radiuses and height respectively, x2 should be null.

```
class CObjshape
{
public:
    void      SetName(CString& str);
    CString   GetName();
    CObj*     GetLastNext();
    CObj*     pParent;
    CObj*     pChild;
    CObj*     pNext;
    Long      ObjType; //Type of objects,
```

```
    AxInfo      m_axInfo;
    SInfo       m_sInfo;
    BOOL        m_Selected;
}
```

(2) Layout space knowledge

Many papers discussed regular object packing problem, such as cuboids, rectangles, and circles, but there are more irregular objects in practical applications. Layout space can be simplified to the combination of primitives (rectangles, cylinders and cone frustum). As shown in figure 4, three virtual primitives are added to layout space as layout objects, which make layout space being a regular cuboid. These primitives' positions are fixed and can not be moved or rotated. In results subsystem, these primitives will be cut and do not be shown on screen.

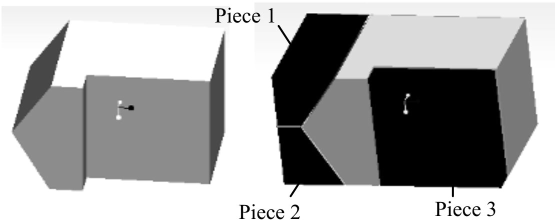


Figure 4. Presentation of layout space

4.2 Rule knowledge

```
class rule          //  rule class
{
    CString numb;   //      rule name
    pre_c  pre;     //      rule condition
    con_c  con;     //      rule conclusion
    CString explain;//  rule explain
    double realiable;//rule reliability
 }
class pre_c     //      rule condition class
{
    rule_c aim;   //  rule object
    CString rel;  //  comparerelation
    CString val;  //  compare value
}
class con_c     //      rule conclusion
{
    CString fun;  //  modify mode
    rule_c aim;   //  rule object
}
class rule_c    //  rule object class
{
    CString att;  //   side
    CString obj;  //   slot
```

```
        rule_c next;  //     next rule condition
  }
```

Compound knowledge model is set up by object oriented and data structure is described by array. This expression method has some traits: (1) Rule and slot are not limited in quantity; (2) Knowledge base can be easily maintained; (3) Performance of intelligent layout system improves.

4.3 Constraint knowledge

There are three kinds of connection between parts defined as following: axis connection, distance and adjacent constraint. A knowledge expression example of axis connection is given as following.

```
 class constraint1          //        constraint I
 {
        int idc;            //        constraint ID
        CString froms;      //        part1 ID
        Int facet;          //        part I face
        CString direction1; //  part position（top, //down. front, back, left, right）
         int tos;    // part2 ID
        int tofacet;  //  part 2 face
        CString direction; //part 2 position （top, //down. front, back, left, right）
 }
```

4.4 Reasoning

Subsystems send reasoning requirement messages to meta-system, and then meta-reasoning machine searches corresponding knowledge base according to the received messages. Design target or requirements are converted to the format which matches with knowledge precondition, and then tasks are assigned to corresponding module. If fact matches with certain rules, reasoning result will be sent to the subsystems. As multi-domain knowledge in involved in packing problems, uncertainty reasoning and hybrid reasoning are adopted in the intelligent layout design.

5 Conclusions

The objects of packing problem with behavioral constraints are in there-dimension. The packing problem belongs to NP-hard problem in math and complex engineering system problem in systems engineering. This paper provides the method for human-computer interactive intelligent packing design based on distributed knowledge. In virtue of the intelligence engineering, the basic theory and the whole frame of the intelligent packing design system based on human computer cooperation are built. Packing design knowledge is expressed in object oriented. This method proved highly effective.

Acknowledgement

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A Fuzzy QFD Approach for Designing Internal Processes for Air Cargo Transportation Services

Shuo-Yan Chou[a,1], Yao-Hui Chang[a,b] and Chih-Hsien Chen[c]
[a] *Dept. of Industrial Management, National Taiwan Univ. of Science & Technology*
[b] *Department of Industrial Management, Lunghwa Univ. of Science and Technology*
[c] *Dept. of Industrial Engineering and Management, Lee-Ming Institute of Technology*

Abstract. The objective of this study is to develop an integrated approach to process design for air cargo transportation. This work integrated the methodologies of fuzzy set theory (FST), balanced scorecard (BSC), and theory of constraints (TOC) to ensure that the internal process design meets the needs of employees, shareholders, and customers, concurrently. This integrated approach is constructed by three stages. In the first stage, the strategies, strategic objectives, and key performance indicators (KPIs) of the company are developed through the conceptual framework of BSC. In the second stage, the initiator's actions are developed through the five logic tools of TOC. Furthermore, in the third stage, through the integration of BSC and TOC with fuzzy quality function deployment (QFD), KPIs and initiator's actions were transformed into the design requirements and the technical requirements. Finally, the house of quality (HOQ) is built for designing the service process of air cargo transportation based on fuzzy QFD.

Keywords. air cargo transportation, fuzzy quality function deployment, fuzzy set theory, balanced scorecard, theory of constraints.

Introduction

Air cargo transportation industry has three characteristics: strict control, peak time influence, and internationalization. Because of these factors stated above, air cargo transportation industry is very distinctive from traditional transportation industry. Therefore, the process management is also a crucial to air cargo transportation industry according to the complexity of air cargo transportation logistics chain and the characteristics of air cargo transportation industry.

As air cargo industry focuses on process management beyond organizational boundaries, there is a need to develop an integrated process design for air cargo transportation. The most logical and viable alternative under the present circumstances would be to become more efficient through better design of existing facilities, resources and process flow. In our study, we are concerned with process design of the air cargo transportation. Meanwhile, the purpose of this study is to propose an integrated process design based on BSC, TOC, QFD, and FST for air cargo transportation.

1. Literature Review

Ahn [1] employed the BSC framework proposed by Kaplan and Norton [2]-[5] to integrate a company's mission, values, vision, strategy into the four perspectives of

[1] Corresponding Author: 43 Keelung Road, Section 4, Taipei, Taiwan; sychou@im.ntust.edu.tw.

BSC, which subsequently evolve into the company's performance targets and indicators. With respect to applications in the field of transportation, Poli and Scheraga [6] designed a BSC framework to elucidate customer satisfaction from five perspectives. The results revealed that transportation operators must find a balance among all quality perspectives and prioritize the needs of key customers. Rouse, Putterill, and Ryan [7] spent four years monitoring the performance and studying the control systems used by international airlines in maintenance.

Goldratt proposed the TOC in 1982, the complexity of a factory is decided not only by the number of constraints, but also by the relativity of the constraints. Rahman [8] indicated that in order to address the policy constraints and effectively implement the process of on-going improvement, Goldratt developed the TP in 1990. Therefore, the TP of TOC is a systematic approach for investigating, analysis, and solving complex design problem [9]- [11]. Besides, Klein and Debruine [12] presented a TP for establishing management policies of American companies.

QFD process may input various linguistic data, which are assessed with human perceptions and judgments. As such, QFD process typically involves the imprecision and vagueness inherent in linguistic assessment. This environment can be to imprecision with the help of FST [13]. As a result, it has been widely used in QFD recently [14]-[17].

Companies having implemented QFD have reported a variety of advantages and also shortcomings with method [18], [19]. Several approaches have been made to overcome the shortcomings in working the QFD process. Two of these trends are considered in this work: application of the FST and homo/heterogeneous group decision making to determine priorities of design requirements and technical requirements in QFD.

2. Derivation of Equations

This work integrated the methodologies of BSC, TOC, and fuzzy QFD to ensure that the service process design meets the needs of employees, shareholders, and customers, concurrently.

BSC seeks for the balance of short-term objectives and long-term objectives, financial perspective and non-financial perspective, lagging indicators and leading indicators, quantitative indicators and qualitative indicators, local performance and global performance, internal performance and external performance, and top-down analysis and bottom-up analysis.

This paper, for satisfying the need of customers and the commitment of shareholders, applies BSC in service process design to develop KPIs for air cargo transportation. Mission statement transform into KPIs by the top-down procedure, whereas the four perspectives analysis are gained by the bottom-up procedure. Through HOQ of QFD, this study also transforms KPIs to design requirements.

General speaking, there are two kinds of organization's limitations which is physical constraints and policy constraints. There are three main physical constraints of an organization. Number one, vendors' constraints, most of the companies complain about the vendors, but this normally won't be a real constraint. For example, a company might face shortage of material supply, the root cause might be the ineffective of its procurement or inventory strategy, not caused by vendor – except for when vendor face a continuous lack of supply of material (normally it happens to the

whole industry). Resource constraints are the second constraint, and market constraints are the third constraint [10]. However, the policy constraints include behavior constraint, managerial constraint, and logistical constraint.

Five logic trees have been developed by Goldratt's TP. That helps to solve physical constraints and policy constraints. TP has probed the core problem deeply by the current reality tree (CRT). TP finds out conflict conquering win-win alternatives in order to enhance process quality and effectiveness by the evaporating cloud (EC) diagram and future reality tree (FRT). The final step, pre-requisite tree (PRT) and transition tree (TT) infer the effective alternatives and initiator's actions in order to solve the core problem and achieve the desirable effects.

QFD is a well-structured design tool; HOQ is the core of QFD. The conventional HOQ to quantify the relationships is accomplished using 3-point scale or 5-point scale to denote relationships between each WHATs and each HOWs [20]. However, in practice the relationships are usually vague and imprecise, and can be described in linguistic terms. In this work, the relationships are represented as linguistic terms, and conversion scales are applied to transform linguistic terms into fuzzy numbers. A scale of five for importance weight and relationship are used in this study.

Table 1 presents relative importance of WHATs and relationship between each WHATs and each HOWs considered as linguistic variables. The trapezoidal fuzzy number is easy to use and interpret. For example, a very significant weight of a specific requirement can be measured by a trapezoidal fuzzy number and denoted by (7, 10, 10, 10).

Table 1. Linguistic variables and fuzzy numbers for the relative importance or relationship

Relative importance	Relationship	Fuzzy numbers
Very Low (VL)	Very Weak (VW)	(0, 0, 0, 3)
Low(L)	Weak (W)	(0, 3, 3, 5)
Moderate(M)	Moderate (M)	(2, 5, 5, 8)
High(H)	Strong (S)	(5, 7, 7, 10)
Very High (VH)	Very Strong (VS)	(7, 10, 10, 10)

After obtaining the necessary data from the participants in the company, the following computational procedure is performed to determine the normalized design requirement scores. The arithmetic operations on trapezoidal fuzzy numbers are employed.

Step 1: Determine the degree of importance (or reliability) of the participants. If the degrees of importance (or reliability) of participants are equal, then the group of participants is called a homogeneous group. Otherwise, the group is called a heterogeneous (non-homogeneous) group [21].

Assume that there are k participants $\left(D_t, t = 1, 2, ..., k\right)$ who are responsible for assessing the relationship between m HOWs $\left(A_i, i = 1, 2, ..., m\right)$ and n WHATs $(C_j, j = 1, 2, ..., n)$ as well as the importance of the WHATs. The degrees of importance (or reliability) of participants are $I_t, t = 1, 2, ..., k,$ where $I_t \in [0,1]$ and the sum equal to 1. If the relative importance (or reliability) and weight of each participant is considered, then the most important participant is selected among participants and a weight of 10 is assigned, i.e., $\omega_t = 10.$ Furthermore, the lth participant is compared with the most important participant and a relative weight for the lth

participant $\omega_l, l = 1,2,...,k$, where $\omega_l \in I$ and $\omega_l \in [0,10]$, is obtained. Finally, the degree of importance I_t is defined as follows:

$$I_t = \omega_t / \sum_{t=1}^{k} \omega_t, t = 1,2,...,k. \quad (1)$$

If $I_1 = I_2 = ... = I_k$, the group of participants is called a homogeneous group; otherwise, the group of participants is called a heterogeneous (non-homogeneous) group.

Step 2: Introduce linguistic weighting variables (Table 1) for participants to assess the fuzzy relative importance of WHATs (customer needs), and then compute aggregated fuzzy relative importance of WHATs.

Let $\tilde{W}_{jt} = \left(a_{jt}, b_{jt}, c_{jt}, d_{jt}\right), j = 1,2,...,n;\ t = 1,2,...,k$, to be the linguistic weight given to WHATs $C_1, C_2, ..., C_n$. The aggregated fuzzy relative importance, $\tilde{W}_j = \left(a_j, b_j, c_j, d_j\right), j = 1,2,...,n$, of WHATs C_j assessed by k participants is defined as:

$$\tilde{W}_j = (I_1 \otimes \tilde{W}_{j1}) \oplus (I_2 \otimes \tilde{W}_{j2}) \oplus \cdots \oplus (I_k \otimes \tilde{W}_{jk}), \quad (2)$$

where $a_j = \sum_{t=1}^{k} I_t a_{jt}, b_j = \sum_{t=1}^{k} I_t b_{jt}, c_j = \sum_{t=1}^{k} I_t c_{jt}, d_j = \sum_{t=1}^{k} I_t d_{jt}$.

Step 3: Use linguistic relation variables (Table 1) for participants to assess the degree of relationship between each WHATs and each HOWs, and then pool them to obtain the aggregated fuzzy relationship between each WHATs and each HOWs.

Let $\tilde{x}_{ijt} = \left(o_{ijt}, p_{ijt}, q_{ijt}, s_{ijt}\right), i = 1,2,...,m, j = 1,2,...,n, t = 1,2,...,k$, be the linguistic suitability degree of relationship between each WHATs and each HOWs assigned to HOWs A_i for WHATs C_j by participant D_t. Let us further define $\tilde{x}_{ij}$ as the aggregated fuzzy relationship between HOWs A_i and WHATs C_j, such that

$$\tilde{x}_{ij} = (I_1 \otimes \tilde{x}_{ij1}) \oplus (I_2 \otimes \tilde{x}_{ij2}) \oplus ... \oplus (I_k \otimes \tilde{x}_{ijk}), \quad (3)$$

which can subsequently be represented and computed as

$$\tilde{x}_{ij} = \left(o_{ij}, p_{ij}, q_{ij}, s_{ij}\right), i = 1,2,...,m, j = 1,2,...,n, \quad (4)$$

where $o_{ij} = \sum_{t=1}^{k} I_t o_{ijt}, p_{ij} = \sum_{t=1}^{k} I_t p_{ijt}, q_{ij} = \sum_{t=1}^{k} I_t q_{ijt}, s_{ij} = \sum_{t=1}^{k} I_t s_{ijt}$.

Step 4: Construct a fuzzy relationship matrix based on fuzzy relationships.

The fuzzy relationship matrix $\tilde{M}$ can be concisely expressed in matrix format:

$$\tilde{M} = \left[\tilde{x}_{ij}\right], \quad (5)$$

where $\tilde{x}_{ij}, \forall i, j$ is the aggregated fuzzy relationship of HOWs $A_i, i = 1,2,...,m$ with respect to WHATs C_j.

Step 5: Derive fuzzy HOWs (design requirement) scores are computed by multiplying the fuzzy relationship matrix with the corresponding weight vector W, i.e.,

$$\tilde{F} = \tilde{M} \otimes \tilde{W}^T = [\,\tilde{f}_i\,]_{m\times 1} \quad (6)$$

where $\tilde{f}_i = \left(r_i, s_i, t_i, u_i\right), \ i = 1,2,...,m.$

Step 6: Normalization ensures a more meaningful representation of the fuzzy HOWs scores. Hence, a linear scale of measurement to vary precisely in the [0,1] interval is employed to normalized the resulting HOWs scores as follows:

$$\tilde{N}_i = \tilde{f}_i \ / u^* \quad (7)$$

where $\tilde{N}_i$ denotes the normalized HOWs scores and $u^* = \max_i u_i$.

3. Integrated Framework

The fuzzy QFD takes only customer requirements into consideration for the product design, whereas the design of service process for air cargo transportation have to include customers, employees as well as shareholders requirements into consideration, due to the fact that the process is more complicated and has many upstream and downstream interfaces. Through the application of BSC, consideration of customers, employees, and shareholders requirements, and TOC, analysis of bottleneck process, the authors apply fuzzy QFD to integrate BSC and TOC into HOQ.

This article focuses the research on the internal process perspective and proposes an integrated design framework. First, we use the BSC methodology for a company to develop the framework for establishing its design requirements in the first stage of deployment of fuzzy QFD. In the second stage of deployment of fuzzy QFD, this study applies the TP of TOC to deploy the technical requirements for the internal process perspective. Finally, the HOQ is built for designing the internal process of air cargo transportation based on fuzzy QFD methodology (as shown in Fig. 1).

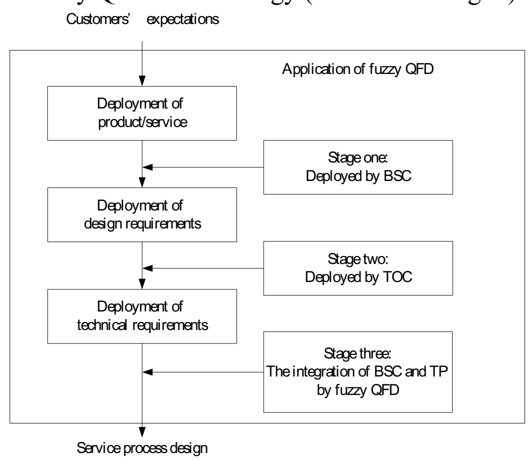

Fig. 1 A design framework for integrating BSC and TOC into fuzzy QFD

Stage one: BSC to meet customer requirements and design requirements

The BSC framework is used to develop the customer requirements and design requirements in this stage to meet in air cargo transportation design (as shown in Fig. 2). It ensures that all employees are in line and are striving toward a common mission.

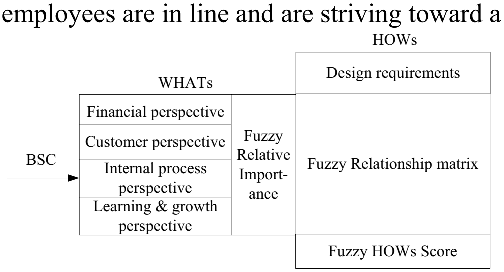

Fig. 2 BSC to meet customer requirements and design requirements

Kaplan and Norton [4] stated that BSC has four characteristics, which help to link the long-term objectives and short-term actions together. First, build consensus through the discussion of company's mission and vision. Second, through cause-and-effect analysis,

strategic map and KPI, link the employee performance to company's overall strategy. Third, incorporation of operation plan and financial plan, to ensure the long-term plan can be implemented. Fourth, build up the feedback and learning systematic through the learning & growth prospective of BSC, so that the company is able to examine and discuss its strategy.

Based on the application of BSC, the financial perspective remains an important tool for companies, since it reflects the results of any actions taken to improve the four perspectives. Customer acquiring, customer retention, and meeting customers' expectations are typically key determinants of customer perspective.

The internal process perspective should enhance the value-add of products or services used by customers. The indicators of employees' learning & growth perspective are used mainly to ensure outstanding internal process, which will in turn be the basis of internal process, customer, and financial perspectives.

Stage two: TP to meet technical requirements

This research utilizes the following three steps of TP of TOC to deploy the technical requirements (as shown in Fig. 3). In the first step, this work applies the five groups of weak links, including behavior constraint, managerial constraint, capacity constraint, market constraint, and logistical constraint, to develop the CRT in the first step. The CRT is a diagram built on the cause-effect relationships between the UDEs and their immediate causes. The objective is to find the core problem—what to change?

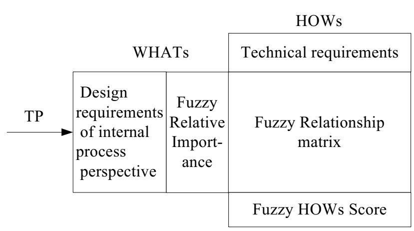

Fig. 3 TP to meet technical requirements

The second step in the TP deals with the search for a solution to the core problem—what to change to? This step consists of the EC diagram and the FRT. After developed the CRT formed by core problems and UDEs, through the EC diagram, second logic tool of TP, we define the desirable objective of core problem. We then find out the conflict that exists in their reality and work out the injection to achieve the desirable objective. The third logic tool of TP is FRT, it is used to model the changes created after defining the injection from the EC diagram and uncover the intermediate objectives.

The objective of the third step in the TP is to find the initiator's actions—How to change? This step consists of the PRT and the TT. The fourth logic tool of TP is the PRT, this is to find and define clearly the intermediate obstacles arise while moving from CRT to FRT. We first define the intermediate objectives of DEs, and then find out the intermediate obstacles to achieve the intermediate objectives, link the intermediate objectives and obstacles to form the PRT. The last logic tool of TP is the TT; this is to help to develop the details of the initiator's actions, where it is developed through solution finding for the obstacles of PRT. All initiator's actions can help to achieve intermediate objectives by overcoming the obstacles, after all intermediate objectives is

achieved, the injection can be achieved, thus solve the core problem. Finally, the initiator's actions construct the technical requirements for the service process design.

Stage three: The integration of BSC and TP with fuzzy QFD

The core of fuzzy QFD is the matrix, called the HOQ. In the first deployment, the four perspectives of BSC constitute the "WHATs" matrix, which are the needs of all the stakeholders, of fuzzy QFD. The procedure of balanced business scorecard for formulating the KPIs can be applied to derive the "HOWs" matrix to meet the customers' requirements associated with fuzzy QFD. In the second deployment, the KPIs of BSC constitute the "WHATs" matrix, which are the design requirements, of fuzzy QFD. The procedure of TP for formulating the initiator's actions constructs the "HOWs" matrix, which can be applied to derive the technical requirements associated with fuzzy QFD.

4. Conclusions

As the air cargo transportation industry incorporates a complex industrial logistics chain, the air cargo transportation industry should focus on process management beyond organizational boundaries. Thus, this study proposes an integrated approach to process design for air cargo transportation based on the methodologies of BSC, TP, and fuzzy QFD. This approach is constructed by three stages. First, we use the BSC methodology for a company to develop the framework for establishing its design requirements. In the second stage of deployment of fuzzy QFD, this study applies the TP of TOC to deploy the technical requirements. Finally, the HOQ is built for designing the process of air cargo transportation based on fuzzy QFD.

The design and redesign of service process for air cargo transportation need huge capital expenditure, thus, it also needs the voice of shareholders and employees, not only the voice of customers. The BSC methodology involves the voice of shareholders, customers, and employees through the four perspectives—financial perspective, customer perspective, internal process perspective, and learning & growth perspective. TP of TOC can also be used to deploy the design requirements of four perspectives, and the technical requirements are built from the five logic tools. Fuzzy QFD can be used to predict problems in advance of operation or post sales service during the design stage. Through fuzzy QFD, the KPIs that developed by BSC can be transformed into the design requirements, and the initiator's actions, which developed, by TP can also be transformed into the technical requirements.

This study only considers the framework and procedures of process design for air cargo transportation is one of the limitations of this research. Therefore, how to apply the proposal method systematically to a case study need to be included in future research. Besides, how to consider the quantitative factors into the proposal method in the development of the optimal model for service process design of air cargo transportation also needs to be included in future work.

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CAD Interactions for Increasing Designers Awareness of Manufacturability

Yvon Gardan [a], Mael Hilléreau [a,1] and Estelle Perrin [b]
[a] *Institut de Formation Technique Supérieur, France*
[b] *Paul Verlaine Metz University, France*

Abstract. This paper outlines the way we think future CAD systems should take into account manufacturing, and more broadly speaking, how they could give support for CE and PLM. We show that DIJA project – which is based on a top-down design methodology called "synthetic design" – is able to connect design tools with manufacturing knowledge. The latter is formalised into rules which are linked to DIJA shape model and design tools, so that designers are advised by the system regarding manufacturing-related considerations. Trade rules are modelled and checked by means of two kinds of graphs which evolve – as the design does – thanks to a tools-integrated propagation mechanism. A prototype is demonstrated through a typical design scenario.

Keywords. Computer-Aided Design, Concurrent Engineering, Product Lifecycle Management, Design for Manufacture

1. Introduction

Today's enterprises economical context brings to light some new trends and issues: reducing time to market so as to increase market shares, getting quality at the best price, and as a result, integrating all product lifecycle aspects at all decision stages. The concepts of Concurrent Engineering (CE) and Product Lifecycle Management (PLM) follow from these assessments. PLM intends to optimise product lifecycle by integrating all product aspects thanks to computational means, while CE aims to switch from sequential to parallel development and decision making paradigms. Providing CE and PLM is a very complex task and requires some effort from all of the protagonists in changing their methodologies of work, as well as providing interoperability, communication support, and knowledge management.

Product development activities may be seen as informational flows. Due to interdependency of decisions, these flows form several loops all along the development process. Supporting CE entails optimising these redesign iterations so as to get closer to the ideal concept: "design it right the very first time" [1]. Concerning design and manufacturing activities, this consists in improving information transit during loops and supporting

[1]Corresponding Author: Mael Hilléreau, IFTS, CReSTIC laboratory, CMCAO team, 7 bd Jean Delautre 08000 Charleville-Mézières, France; E-mail: mael.hillereau@univ-reims.fr.

loops that may be productive but are not forced on by conventional manufacturability analysis. It is already usual for Computer-Aided Design (CAD) systems to supply designers with some numerical simulation or kinematics analysis modules. Although they assist the designer, the aid from these facilities is confined to design trade. Besides, many Design for Manufacturing (DFM) tools were developed but they are not sufficiently integrated with CAD softwares.

This paper points out that DIJA system [2,3] – based on a top-down methodology called "synthetic design" – connects CAD tools with trade knowledge, so that designers are advised in accounting for manufacturing-related considerations. The system models and checks manufacturing trade rules by means of two kinds of graphs which evolve – as the design does – so as to maintain interdependence between design and manufacturing concerns. In this way, DIJA optimises the design process and shortens redesign loops while respecting confidentiality.

In section 2, we look over manufacturing rules, existing DFM approaches, and previous work related to DIJA project. Section 3 presents our approach for providing a shape modelling assistance. A prototype is demonstrated in section 4 through a typical design scenario involving powder metal sintering process. Finally, section 5 concludes the paper and outlines future research trends.

2. State of the Art

2.1. Manufacturing Rules & DFM

It is an accepted fact [4,5,6,7,8] that many manufacturing issues can be expressed by means of mathematical rules. These may be classified depending on their purpose (ease of manufacture/assembly, cost/time optimisation), what element they apply to (assembly, component), and what data is needed (geometry, materials, etc.). In this paper, we focus on rules applied to components, whose purpose is to assess manufacturability, and which mainly involve geometrical data. Many works can be found in the literature that aspire to support non design concerns within design stage. The wide topic of Design for 'X' embraces DFM and others such as Design for Assembly (DFA) [4,5,9,10]. Regarding DFM, two research currents can be confronted.

Variant approaches determine manufacturability by reusing previously experienced design and manufacturing choices [7]. Group Technology and Case-Based Reasoning are examples of such approaches. One obstacle with these approaches is that they need to compare properties of the current part to those of each already designed part, which refers to the designer's intuition. Further, additional work is required to get the design of an old part transcribed to a new one. Such approaches are therefore not truly compatible with a real-time facility. This is not true with the learning method of [11]. This system uses relative manufacturability indices so that to learn which parts are easy to manufacture. The main problem is that design decisions are not intelligible since they are tacitly represented, which is a hurdle for design decisions motivations traceability.

In opposition, generative approaches are based on what is known from the designed part and its manufacturing process without directly considering previous experience. Some of these approaches use heuristic rules in order to establish manufacturability [7] – design features are associated to manufacturability estimations including technological

and economical aspects. In contrast, analytic approaches [12,6] consider directly the manufacturing process through its physical model. One drawback of most of these approaches is that the part has to be broken up into manufacturing features to assess manufacturability. For example, Sánchez et al. [6] associate design features to destructive manufacturing tools. In our sense, this way of considering design activity is erroneous because manufacturers and designers both have – and must keep – their own trade logic.

Manufacturability evaluation is performed at some particular steps of the design. These may be predefined into the design methodology – e.g. for validating overall and detailed design [13] –, or selected by the designer [8].

As a conclusion, many DFM tools were developed, but they are often dedicated to a particular domain, and restrictions about the part geometry and/or topology are also made. Besides, manufacturing knowledge is closely coupled with the CAD model, which is not scalable and does not support confidentiality. Finally, manufacturability is not evaluated in real-time, i.e. it is not performed through the CAD system and continuously during design. In contrast, based on DIJA project, this paper aims to specify an approach for handling such issues.

2.2. DIJA Design System

DIJA [3] is a federal project whose aim is to provide a modular CAD environment accessible from any networked computer, and potentially any kind of user (expert, neophyte). Interests of DIJA include functional modelling, CE and trade-oriented design. Unlike most of current CAD systems, its modelling methodology, called "synthetic design", is based on a top-down modificative (not constructive nor destructive) approach [2]. The user firstly selects a starting shape that roughly looks like the final object. Then, he/she improves the shape step by step in order to adapt it to his/her purpose. The final form is obtained by deforming the surface of the current shape. To provide the user with the most intuitive system, interactions are based on *Dialogue Elements* (DE) which are visible characteristics of the shape (see Figure 1). A *Face* represents a homogeneous surface or a part of it, *Characteristic Lines* and *Characteristic Outlines* make a feature of a visible line on the shape surface, and *Fibres* are lines featuring the shape silhouette. DEs represent any kind of solid (prismatic or exact) and the underlying geometric model is versatile (Boundary Representation, Constructive Solid Geometry. . .) [3].

Based on DEs, only three basic interactions are sufficient to design: *Dividing* for dividing an object into several parts; *Transmutation* for changing the type of an object or an object part; and *Deformation* for deforming an object through its DEs. Of course these interactions may be combined in order to define some higher level tools. All these tools are referred to as *DIJA tools* in the following.

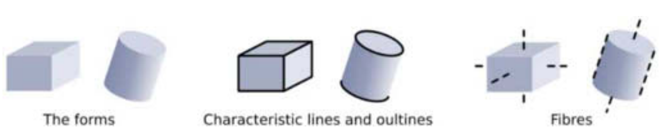


Figure 1. Dialogue elements (DE) on a box and a cylinder.

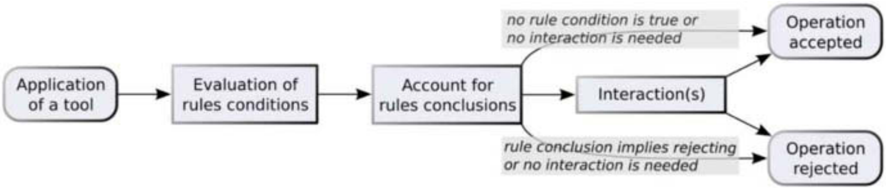


Figure 2. Overall system behaviour.

3. Shape Modelling Assistance

3.1. Global Process

Unlike most of existing approaches, we consider that designers should not have to keep in mind which manufacturing tools are to be used while specifying the shape. Besides, manufacturability analysis should be seen as a permanent facility. Thus, our system responds continuously to the designer's acts and warns him about conflicts at the right time. Consequently, the system may take control over the application and then stop design interactions at any time [14]. Three kinds of manufacturing interactions may take place [14]: prohibition of non manufacturable parts; notification of manufacturing difficulties; and manufacturability recommendations involving collaborative scenarios [15]. Manufacturing rules are factory dependent. They are specified using *conditions* and *conclusion*s (often referred to as "if then" rules – e.g. "if the wall is too thin, then the part is not manufacturable"). Each time the designer applies a DIJA tool, conditions are re-evaluated and a new conclusion may occur for each rule. A conclusion may lead to one or more of the three above manufacturing interactions (see Figure 2). DIJA historic module [3] guarantees that the CAD model remains consistent after cancelling an operation or modifying the same DE multiple times.

The two kinds of graphs presented in [14] are used to manage rules. Precisely, the magnitudes graph is intended to optimise rules conditions assessment whereas states graphs allow to determine and reflect rules conclusions. An example of magnitudes graph is shown on Figure 5(a) in which $D^e = 2 \times D_1$. When F_1^r is modified, the system calculates connected manufacturing values (D_1 in this case), and then manufacturing magnitudes connected to each of these manufacturing values (D^e in this case). In this way, minimal computing is always guaranteed.

3.2. Rules Evolution

DIJA Tool. All in all, a DIJA tool defines the transformation of a set of DEs $\mathbb{E}_1$ into a set of DEs $\mathbb{E}_2$. It is possibly parameterised and user interactive. On Figure 3, E_i is the set of DEs composing the part before applying the tool, and E_f the set of DEs after its application. Set P contains the tool parameters, i.e. DEs required to perform the transformation ($P \subseteq E_i$). E^m, E^c, and E^r are DEs respectively modified, created and removed by the tool. Transformation is thus defined between sets $\mathbb{E}_1 = E^m \cup E^r$ and $\mathbb{E}_2 = E^m \cup E^c$.

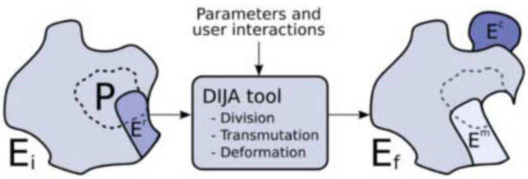
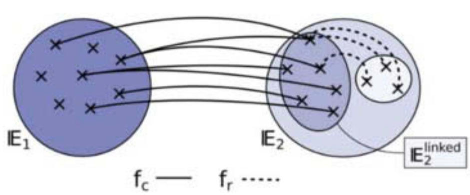


Figure 3. Transformation defined by a DIJA tool.

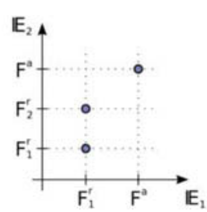
Initial and Tools Rules. Trade rules can be specified by adding some manufacturing magnitudes into the magnitudes graph of the part. Because we adopt DIJA "synthetic design", two ways of specifying rules must be considered: adding manufacturing magnitudes to the magnitudes graph of the initial part, and adding them in the same time as a tool is applied. In both cases, rules may have to evolve when DEs are created or removed (sets E^c and E^r). Tool application is performed in two phases: adaptation of existing rules, and insertion of tool-specific rules. The second phase is not detailed as it is similar to the process of applying rules to an initial part, which just consists in adding new nodes and edges to the graphs.

Rules Adaptation. When a DIJA tool is applied, the system needs to adapt rules which depend on DEs of set $\mathbb{E}_1$ so that they keep their meaning based on DEs of set $\mathbb{E}_2$, i.e. those remaining after applying the tool. Notably, rules connected to DEs of E^r have to be deleted from the magnitudes graph, whereas rules connected to DEs of E^m have to be kept even if their application context has changed (substitution of $\mathbb{E}_1$ for $\mathbb{E}_2$). Further, the way rules have to evolve is conditioned by structural and topological relations. These are represented using the correspondence and referring functions respectively noted f_c and f_r in the following.

Correspondence and Referring Functions. The correspondence function defines to which DE(s) of $\mathbb{E}_1$ – possibly none – each DE of $\mathbb{E}_2$ is structurally linked. Let $\mathbb{E}_2^{linked}$ be the set of DEs of $\mathbb{E}_2$ linked at least to one DE of $\mathbb{E}_1$ – see Figure 4(a). An example of rule evolution is shown in Figure 5. In this example, a design tool is applied to a cylinder that allows to bevel the revolution fibre F_1^r given as a parameter. The correspondence function is defined as $f_c : \mathbb{E}_1 \to \mathbb{E}_2$. In order to specify f_c, we classify DEs of $\mathbb{E}_1$ and $\mathbb{E}_2$ based on the transformation resulting from the tool application. Any structural transformation can be described by a correspondence function. However, there is no uniqueness and the adopted solution is always defined by the tool. An example of correspondence function associated to the application of the tool of Figure 5 is presented on Figure 4(b).

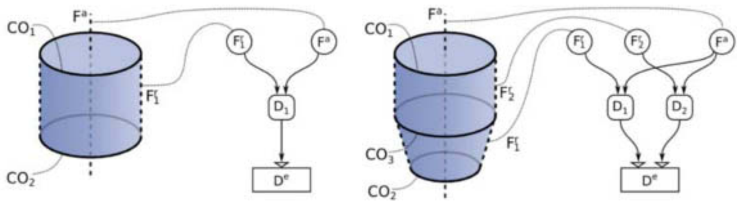


(a) Sets $\mathbb{E}_1$, $\mathbb{E}_2$ and $\mathbb{E}_2^{linked}$



(b) Example of correspondence function

Figure 4. Correspondence and referring functions.



(a) Before transformation (b) After transformation

Figure 5. Example of propagation; $D_{1,2}$: distances; D^e: diameter.

It specifies that axial fibre F^a is unchanged by the tool, and that F_1^r is divided into two revolution fibres F_1^r and F_2^r. This establishes that D_1 must be divided into two manufacturing values D_1 and D_2. All necessary information is not provided by f_c. Indeed, some DEs of E^c may have no antecedent, namely those of $\mathbb{E}_2 - \mathbb{E}_2^{linked}$. But it could be required that they would be involved into some rules related to DEs of $\mathbb{E}_1$. The referring function is intended to determine to which DE(s) of $\mathbb{E}_2^{linked}$ – possibly none –, each DE of $\mathbb{E}_2 - \mathbb{E}_2^{linked}$ should be topologically linked in order to get a correct magnitudes graph. It is defined as $f_r : \mathbb{E}_2 - \mathbb{E}_2^{linked} \rightarrow \mathbb{E}_2^{linked}$. For instance, if the manufacturing magnitude D^e of Figure 5 were also depending on the characteristic outline CO_1 through D_1, propagating the rule would require to make an analogy between CO_3 and CO_1 because D_2 would have to depend on CO_3.

Propagation Process. Several behaviours may be adopted while propagating a rule. The way each rule propagates depends on the way DEs involved into the rule are structurally modified, and on the kind of propagation chosen for the rule. Propagation types are `delete` for deleting the rule, `unchanged` for leaving the rule as is, `split` for duplicating the rule, and `join` for aggregating several rules. Before applying a tool, the system makes a copy of the current magnitudes graph, it deletes DEs of E^r and their connected rules, it then inserts DEs of E^a into the new magnitudes graph, and finally, it looks through all DEs of $\mathbb{E}_1$ and applies the right propagation based on f_c and f_r.

4. Implementation

A prototype of DIJA shape modelling assistance was developed using DIJA Java library. A design scenario is presented on Figure 6. The user firstly selects a cylinder into a library – see Figure 6(a). He/she decreases its diameter – see Figure 6(b). But at some point, the system warns him/her that an additional cost is needed to manufacture the part – see Figure 6(c). He/she rejects the proposal, and so the action is cancelled, which returns back to the design of Figure 6(b). Then, he/she applies a bevel tool – see Figure 6(d). While he/she is setting up parameters, the bevelled part diameter decreases until it reaches a critical value. At this time, thanks to the propagation algorithm, the system warns about another additional cost – see Figure 6(e). This time, the user accepts the condition and the corresponding warning remains highlighted in the application window – see Figure 6(f).

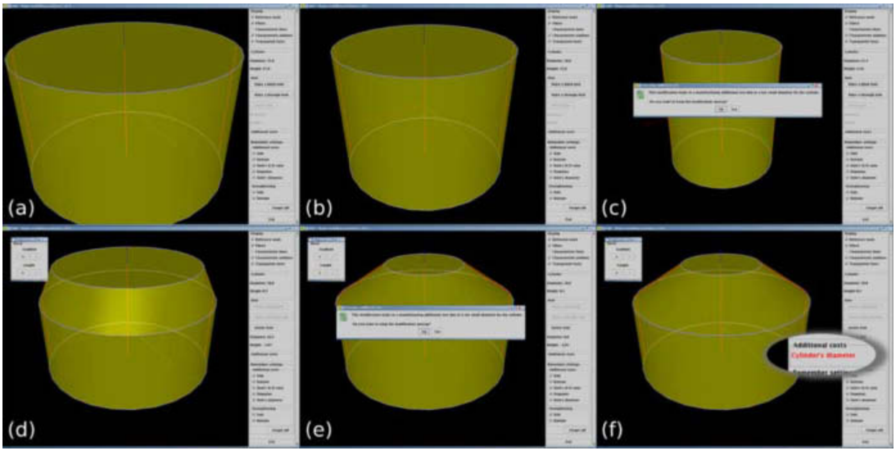


Figure 6. Example of design scenario.

5. Summary and Future Research

In this paper, we presented a shape modelling method directed by manufacturing based on the "synthetic design" methodology. Unlike existing approaches, DIJA shape modelling assistance is performed in real-time, which allows integrating collaboration scenarios to the manufacturability optimisation process, and notifying the designer at the right time. Moreover, it is compatible with analytic and heuristic evaluations regarding any manufacturing process and/or piece. Manufacturing and design knowledge are clearly distinctive so that manufacturers and designers can keep their own trade methodology and vocabulary. This also allows respect of confidentiality. Nevertheless, manufacturability optimisation process is not performed completely automatically. Our claim is that it is not possible to reach manufacturability in a totally automatic way because formalised trade knowledge is often incomplete, and because of the complexity of underlying optimisation issues. We rather pitch on a mixed approach with real-time estimates if available information makes it possible, and flexible interactions with humans.

Academic examples for pedagogic purpose validate the approach. In future, the system will be tried out in industrial cases. In this purpose, a user interface has to be developed for the trade rules to be entered in an intuitive way.

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IOS Press, 2006

Concurrent Conceptual Design of Movable-Counterweights Method

Zhang Ying, Yao Yan-An, Cha Jian-Zhong
College of Mechanical and Electronic Control Engineering, Beijing Jiaotong University, Beijing, China

Abstract. The movable counterweights method is presented for improving the dynamic balancing of mechanisms balanced by counterweight method. Differing from general ones, the movable counterweights are not fixed to the links on which they are placed but free to slip along them or rotate around the attached pivot centers. The process to generate schemes for the movable counterweight is described and hundreds of moving solutions are obtained. In the conceptual design stage of the movable counterweights, a design procedure based on the philosophy of concurrent engineering is developed. Both optimization of the structural parameters and dynamic simulation of various moving solutions are carried on simultaneously under an integrate circumstance of MATLAB and ADAMS. Results obtained can help designers to evaluate the alternative schemes numerically at the conceptual design stage and select a promising one for further design. Examples are given to illustrate the design procedure.

Keywords. Dynamic balancing, Counterweight, Movable counterweight, Concurrent design, Conceptual design

INTRODUCTION

In industry, more and more high-speed machinery has been designed for increasing productivity and efficiency. For such machines, mass imbalance of the moving links brings about an increase of shaking forces and shaking moment on their foundations. The higher the speed, the greater are the vibrations, noise, unnecessary wears and fatigue, as well as energy consumption. For these reasons, much attention has been paid to the problem of dynamic balancing of the mechanisms and many methods and solutions have been developed and documented [1,2,3]. The counterweight method, which is based on mass redistribution of the mechanism by adding counterweight to the moving link, has been widely used in the dynamic balancing of kinds of mechanisms.

However, it has been shown when the shaking force is balanced by the counterweight method, it usually tends to cause an increase in joint forces, input torques, as well as shaking moment, thus degrading the dynamic performance of the mechanism.

In order to overcome above shortcoming, we proposed a novel movable counterweights method [4]. Unlike the traditional counterweight, which is normally fixed to the link, the counterweight with the proposed method is mounted on the

moving link of the original mechanism through a kinematic pair and, as a result, it is free to move relative to the link where it is attached. In the conceptual design stage of the movable counterweight method, a concurrent design procedure is adopted.

1. Problem Definition

For an in-line crank-rocker mechanism shown in Figure 1, the principal schemes for shaking force balancing are presented in Table 1. Generally, complete shaking force balancing of the linkages can be achieved by placing counterweights on crank 2 and rocker 4 at the same time, marked as scheme3, while partial shaking force balancing can be obtained by attaching a counterweight on crank 2 or rocker 4, respectively, marked as scheme1 and scheme2. For either schemes mentioned above, the counterweights are fixed to the links they are attached on and have the same angular velocity.

As stated, the movable counterweights method aims at improving the dynamic performance of the mechanism balanced by counterweights through the motion of the counterweights. For this purpose, design procedure of the movable counterweights method is developed in following text.

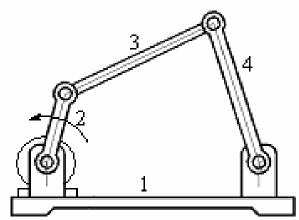
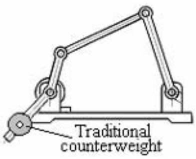
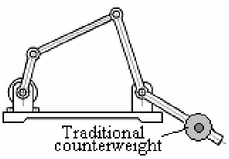
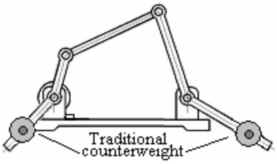


Figure1. Sketch of crank-rocker mechanism

Table1. Traditional schemes for shaking force balancing

Scheme1	Scheme2	Scheme3
		

2. Conceptual Design

Concept design is the most important stage of the whole design process. This is also true in the design of movable counterweights. A number of attempts have been done to achieve an optimum result.

2.1. Generation of the Design Schemes

Considering the possible motion types of the counterweight may be translation or rotation, the movable counterweight is mounted on the moving link of the original mechanism through a revolute joint or a translation joint, which allows it to rotate around the attached pivot center or slip along the link.

Both the translation and rotation of the counterweight can be accomplished by adding additional mechanisms or additional power. While the translation of the counterweight is achieved through additional mechanisms, there are two types of the input-output motion relationships between the input link of additional mechanism and the counterweight, namely, rotation-to-translation and translation-to-translation. Mechanisms that can transform a rotational motion into a translational motion and that can transform a translational motion into a translational motion are both listed in Table2.

Furthermore, for each type of the additional mechanism, there would be three possible positions of the original mechanism to be connected with. For schem1 with one counterweight attached on the input link, if a slider-crank (dyad) is selected as the additional mechanism, it can be added on the coupler link, the output link, or the ground, shown as t1.1a, t1.1b and t1.1c in Table 3. It is also true for other schemes in Table 3 and Table 4. All the possible translation schemes of the movable counterweight through additional slider-crank mechanism are shown in Table 3 as t2.1a- t2.1c and t3.1a- t3.1i, and the total comes to 15(=2×3+9).

Table 2. Possible types of additional mechanisms and additional power

Motion Mode		Possible Types of Additional Mechanisms	Possible Types of Additional Power
Translation	Rotation-to-Translation	slider-crank(dyad) rack-and-pinion, cam-follow	motor and ball screw
	Translation-to-Translation	double-slider wedge cam-follow	hydraulic cylinder pneumatic cylinder
Rotation	Rotation-to-Rotation	spur gear , noncircular gear internal gear pair cam-follower friction rollers pair crank-rock, double-crank, double-rocker } dyad pulley-belt sprocket-chain	electric motor fluid motor

Table 3. Partial schemes for counterweights sliding along the links they attached on

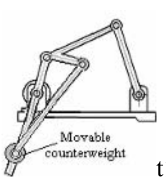
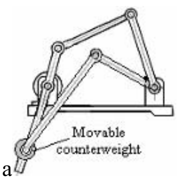
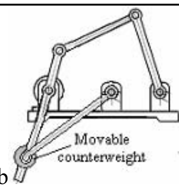
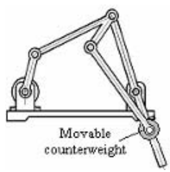
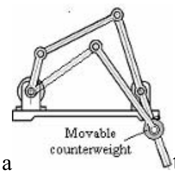
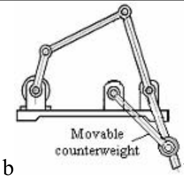
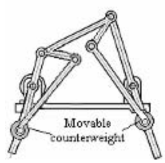
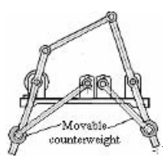
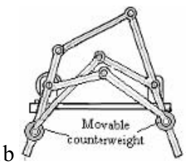
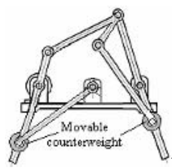
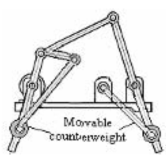
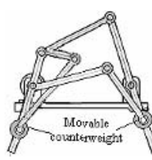
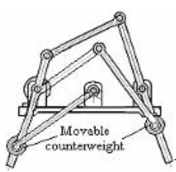
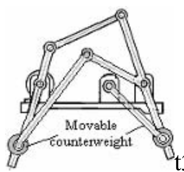
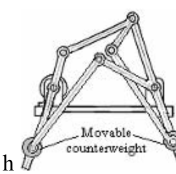
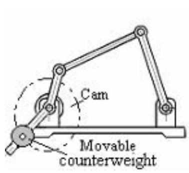
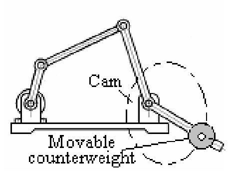
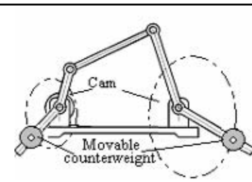
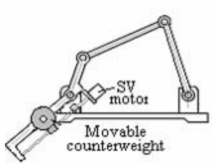
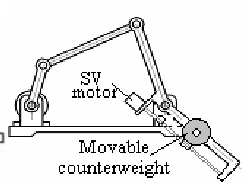
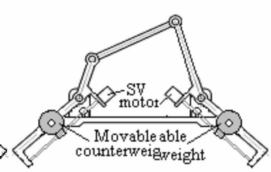
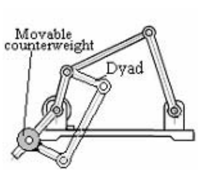
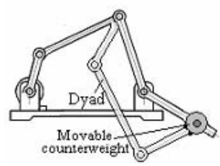
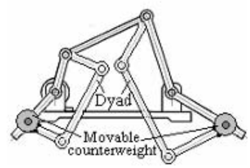
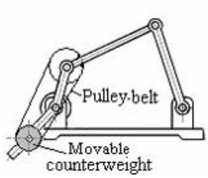
Items		Schemes		
Moving By adding dyads	Schemes based on scheme1	 t1.1a	 t1.1b	 t1.1c
	Schemes based on scheme2	 t2.1a	 t2.1b	 t2.1c
	Schemes based on scheme3	 t3.1a	 t3.1b	 t3.1c
		 t3.1d	 t3.1e	 t3.1f
		 t3.1g	 t3.1h	 t3.1i
Moving by adding Cam fixed to link		 t1.2	 t2.2	 t3.2
Moving by additional drivers		 t1.3	 t2.3	 t3.3

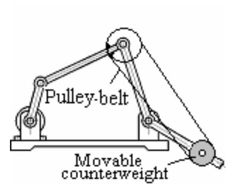
Table 4. Partial schemes for counterweights rotating around the pivots it attached

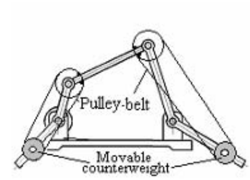
<table>
<tr><th>Items</th><th>Schemes based on scheme1</th><th>Schemes based on scheme2</th><th>Schemes based on scheme3</th></tr>
<tr><td>Moving by additional dyads</td><td>

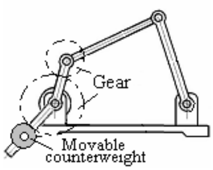
r1.1</td><td>

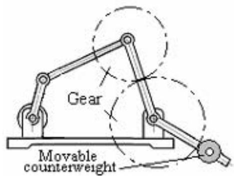
r2.1</td><td>

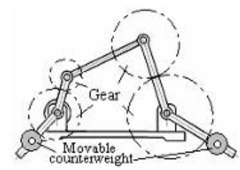
r3.1</td></tr>
<tr><td>Moving through Belt transmission</td><td>

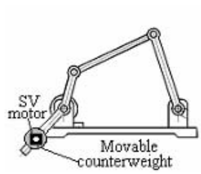
r1.2</td><td>

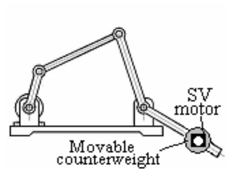
r2.2</td><td>

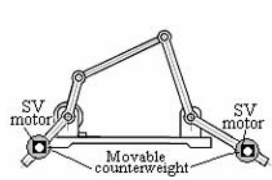
r3.2</td></tr>
<tr><td>Moving through Gear transmission</td><td>

r1.3</td><td>

r2.3</td><td>

r3.3</td></tr>
<tr><td>Moving by additional drivers</td><td>

r1.4.</td><td>

r2.4</td><td>

r34</td></tr>
</table>

According the information shown in Table 2, the total amount of possible moving schemes of the movable counterweight is 146. Considering the possible combination of different additional mechanisms, the total amount will be increased.

For so many alternative schemes or solutions, it is difficult to determine which one is the best. Even though one knows which is the most satisfactory scheme for a certain design requirement, it might not be a satisfactory one when the requirement varies.

2.2. Concurrent Design Concept

Generally, a typical process of mechanical design consists of six steps, which starts with problem definition and ends with communication of the design, as shown in Figure 2. Traditionally, the design stages are connected in series. After identifying the

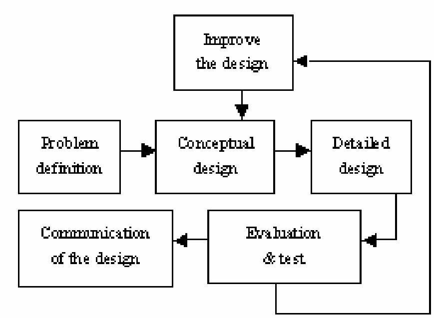


Figure 2. General process of mechanical design

design problem, designers need to find out all possible solutions of the problem meeting the given design requirements, then select one or more solutions from them based on their experience or statistical information. Evaluation phase follows the detailed phase. Whether the selected one is the most suitable one or not only can be evaluated after detailed design phase through kinematic and dynamic analysis, or even after production of the prototype through the results of the experiments. Therefore, it is important to make correct decisions during the conceptual design process so that costly redesigns at later stages can be avoided. Especially for an original design, designers may not consider all the relevant design factors if they are lacking expertise and related information, and as a result, the risk for making an incorrect decision is inevitably existed.

As mentioned above, among hundreds of schemes for the novel movable counterweight, we do not know which one is the most promising one and thus cannot make decisions. If we adopt the normal design method shown in Figure 2 to all the schemes one by one to see how well they work, since the evaluation follows the detailed design, a large amount of work and time are needed for so many schemes.

In order to mitigate these problems, we proposed a design procedure for conceptual design of the movable counterweights based on the philosophy of concurrent engineering [5], which is shown in Figure 3. The strategy is to evaluate mechanical design details of various solutions concurrently at the conceptual design phase, where the designers usually focus on the best conceptual configurations or rough outlines of design ideas. With the help of MATLAB and ADAMS software, the performance of the machine and proposed alternative ideas could be estimated numerically.

2.3. Structural Optimization

For each scheme generated in section 2.1, it is necessary to find out the suitable structure parameters that satisfy the design requirements. The optimal parameters for different schemes are obtained concurrently through the optimization procedures, which are programmed by using MATLAB function from optimization toolbox.

From a global perspective of the dynamic performance, a combination of shaking moment, input torque and shaking force is taken as the objective function. It is aimed at minimizing the root-mean-square (RMS) values of the shaking moment, shaking force and the fluctuation value of the input torque in this study. $f_1(x)$, $f_2(x)$ and $f_3(x)$ are

the fluctuation value of the input torque, RMS shaking moment and RMS shaking force undergoing a circular rotation, respectively.

$$f_1(x) = F_{sRMS} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} |F_S|^2 d\varphi_1} \tag{1}$$

$$f_2(x) = Max(M_{in}) - Min(M_{in}) \tag{2}$$

$$f_3(x) = M_{sRMS} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} |M_S|^2 \, d\varphi_1} \tag{3}$$

Taking the weighted sum of $f_1(x)$, $f_2(x)$ and $f_3(x)$ as the objective function. The optimization problem can be defined as

Minimizing

$$F(x) = w_1 f_1(x) + w_2 f_2(x) + w_3 f_3(x) \tag{4}$$

subject to

equality constraints

$$c_j(x_1, x_{2,} \ldots x_i) = 0, j = 1, \ldots, n_c \tag{5}$$

and inequality constraints

$$g_j(x_1, x_{2,} \ldots x_i) < 0, j = 1, \ldots, n_g \tag{6}$$

where, w_1, w_2, w_3 are the weighting factors**,** which could be adjusted to satisfy different design requirements. $x_1, x_{2,} \ldots x_i$ are design variables, which are structural parameters of the additional mechanisms including the length, mass, inertia moment with respect to each centroid, and the position parameters of the centroid of each member of the mechanism.

For different schemes listed in Table 3, Table 4 and others unlisted ones, design variables and constraints of the optimization problems are different. Thus, a series of optimization programs are developed for kinds of schemes in order to optimize their structural parameters at meantime.

Taking the scheme t1.1a (shown in Figure 4) as example, the design variables are the structural parameters of additional dyad

$$\boldsymbol{X} = [l_5, l_6, m_5, m_6, m_e, J_5, J_6, J_e, \alpha]^T \tag{7}$$

where, $l_5, l_6, m_5, m_6, J_5, J_6$ are the length, mass and inertia moment of link5 and link6, m_e, J_e are the mass and inertia moment of the counterweight, and α is the angle between link 2 and link 5.

Constraints are

$$
\begin{aligned}
& g_1 : -m_e \le 0 \\
& g_2 : -J_e \le 0 \\
& g_j = l_{i0} - l_i \le 0,\ i = 5{,}6; \quad j = 3{,}4 \\
& g_j = l_i - l_{i1} \le 0,\ i = 5{,}6; \quad j = 5{,}6 \\
& g_7 : l_5 - l_6 \le 0 \\
& g_8 : |\alpha| - 360° \le 0
\end{aligned}
\tag{8}
$$

After optimization, the results are transmitted to ADAMS for further information.

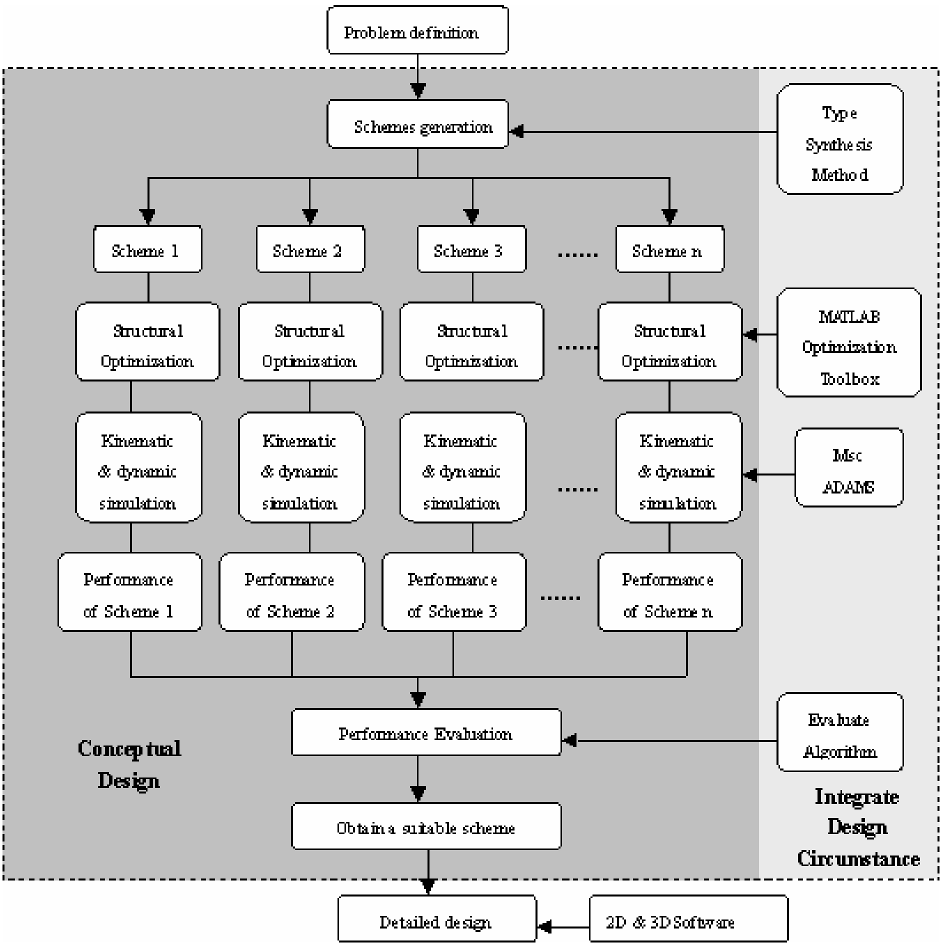


Figure 3. Design procedure of movable counterweights

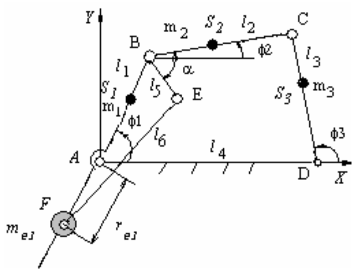


Figure 4. Crank-rocker mechanism with a movable counterweight on crank 2

2.4. Simulation

While the structural parameters are transmitted to ADAMS, a virtual machine model of each possible scheme can be established and dynamic simulation for different schemes is carried out in circumstance of ADAMS software concurrently. Information obtained would help designers to find the most promising alternative.

Scheme t1.1a, t2.1a and t3.1a, shown in Table 3, are taken as examples to illustrate the process. Their concurrent optimization and simulation model are shown in Figure 5.

2.5. Performance Evaluation

Up to now, information needed to make a decision is obtained. The evaluation can be made through performance comparisons depending upon different circumstances and applications. Following are the steps for performance evaluation.

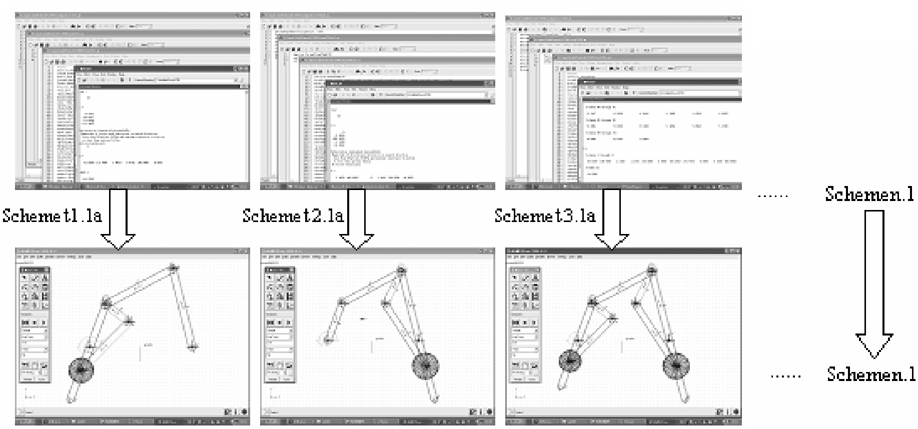


Figure 5. Example for concurrent optimization (MATLAB) and simulation (ADAMS) for different schemes

All alternative schemes must be compared with the traditional ones first. Then the schemes with better performance are compared with each other in following ways:

Different additional mechanisms with same motion mode added for Scheme1, 2, and 3, respectively;

- Same additional mechanism added on different locations;
- Different additional mechanisms on the same locations;
- Different motion mode;
- Different driven ways with same motion mode

According to the result of the evaluation, one or more schemes can be selected for further design.

Only for illustrating the design process, we assume that scheme t1.1a, t2.1a and t3.1a are alternative solutions of movable counterweight for the crank-rocker mechanism to be balanced. The dynamic performance of these three schemes obtained through ADAMS simulation is shown in Table 5 and Figure 6.

Firstly, each scheme should be compared with the traditional one, t1.1a with Scheme1, t2.1a with Scheme2 and t3.1a with Scheme3, respectively.

Then, they are compared with each other according to different design requirements.

If we aim at obtain the optimum dynamic performance of the mechanism only, scheme t3.1a is the most promising one of three schemes.

But if we aim at obtain the optimum dynamic performance of the mechanism with the simplest structure, scheme t1.1a will be the most suitable one.

Obviously, different schemes will be selected for different requirements, and as a result, the selected one will step into the detailed design stage.

It can also be observed in Table5 and Figure 6 that the dynamic performance of the mechanism, especially input torque, can be improved by using movable counterweight method.

Table 5. Comparison example of the dynamic performance of different movable counterweight schemes

Index	Fs · RMS (N)	Max(Min) -Min(Min) (N · mm)	Ms · RMS (N · mm)	Mass of counterweight (kg)		Sum of the length of additional dyad (mm)	
Scheme 1	1.9853	642.2915	614.2896	0.9192		0	
Scheme 2	1.7707	1250.2068	1690.4010	1.3160		0	
Scheme 3	0	1039.2699	1252.0011	m_{e1}	0.55	left	338.8422
				m_{e2}	0.86	right	500.002
t1.1	3.7879	495.3996	707.5712	0.1824		308.6395	
t2.1	4.0919	620.7256	722.2926	2		301.0716	
t3.1	3.8746	486.3979	690.3776	m_{e1}	0.1154	left	338.8422
				m_{e2}	0.0100	right	500.002

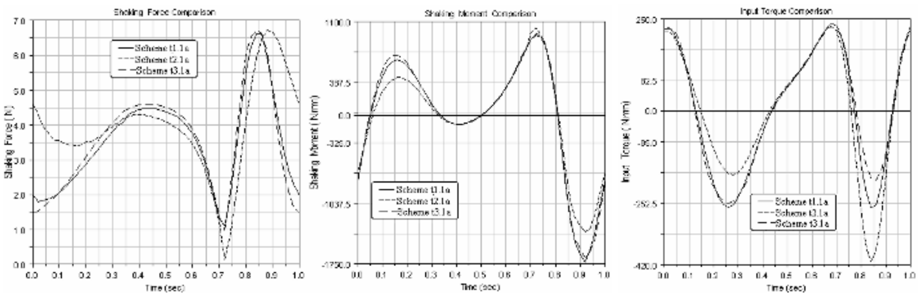


Figure 6. Comparisons of the dynamic performance of scheme 1.1a, 2a and 3a

3. Conclusions

To summarize, the main concerns of the paper are as follows:

(1) Concept and design procedure of a movable counterweight method for dynamic balancing of mechanisms are presented. A crank-rocker mechanism is chosen as the reference mechanism, for which hundreds of counterweight moving schemes are obtained based on the analysis of possible motion modes and driven ways of the counterweights.

(2) A concurrent design method is adopted in the conceptual design phase of the movable counterweights. Various moving schemes are processed in parallel under the integrated circumstance of MATLAB and ADAMS, which supports concurrent numerical evaluation of the alternative schemes and decision-making in obtaining suitable solutions at the conceptual design stage.

(3) An example is given to illustrate both the concurrent design procedure and the effectiveness of the movable counterweights method in improving the dynamic performance of the mechanism balanced by counterweights.

Acknowledgements

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Proposal for a product model dedicated to the foundry industry

Lionel Martin*, George-Florin Moraru and Philippe Véron
LSIS (IMS team), ENSAM

Abstract: Previous studies explain the need of a consistent framework for designing cast part in a concurrent engineering context. After a brief state of the art of product model, this study proposes such a product model dedicated to the cast designer. This model uses an object oriented approach and is based on raw data organization. This new model is described and its capabilities are explained.

Key Words: concurrent engineering, integrated design, product model, design for casting

1. Introduction

Years ago, development of new design was known to be a pure creative act from the designer: the fine art of design. Though, industrial every day's design often consists in organizing elementary tasks and simple communications among various design actors. Moreover, studies had shown that several aspects in design can be formalized [1] and reproduced. Now, even if human creativity still keeps an important place in design process, artificial intelligence or computer can (and have to) be programmed in order to accomplish singular designer's tasks.

The present study takes place in this context, where, in the foundry industry, for productivity and quality requirement, computer or more precisely computer aided tools are inevitably used: for communication, calculation, visualization and storage purpose.

1.1. State of the art

Previous studies [2] [3] try to improve design for casting process working on tasks organization. This approach was limited by the lack of organization among numerical model (the virtual cast part) and so for data constituting those models. The more apparent aspect of this limitation is the fact that, with nowadays commercial tools, it is impossible to obtain global consistency among various CAD model. Design for casting needs a consistent framework organizing design data and leading design actors.

Though, this work partially meets Xiu-Tian Yan's [4] point of view and recommendation: *Without committing further expense to develop super-computer design support systems, how the current systems are being best used becomes an important issue and research avenue for investigation.* The problem is that commercial

* Corresponding author: Ensam, Cours des Arts et Métiers, 13617 Aix-en-Provence, France.
- Email: lionel.martin@ensam.fr

software developers can not always imagine and program all possibilities of interaction for their product with other software. And even if they did, the combinatory number of modules to develop would be too important. The fact is, from the author point of view, extra interface software need to be achieved, not necessarily stand alone software, in order to use current software at their maximum capabilities. Moreover, this interface should be build on the basis of a framework ensuring global consistency: the product model.

This notion of product model has already been studied in other domains except authors do not agree on a universal definition. Here is a brief panel of definitions:

- For some authors [5][6] the act of design is taken as a mathematical problem to solve. This is made possible by a whole formal transcription in mathematical terms of the problem. The problem is that human knowledge cannot be always formalized and sometimes choice have to be made on the basis of incomplete or even missing information.
- For others, design is a sequence of cognitive phenomena happening inside designer's brain [7] in other words: "how do creativity born?" This creative part of design can be assisted thanks to [8].
- Designer's knowledge and product information needs to be archived in a way to be easily and rapidly reusable. Studies[9] are then centered on product data management (PDM) and access to databases.
- Communication media are key tools for concurrent engineering. That is why some authors [10] place the way information are exchanged, distribute in a central place for the product model.
- In order to work efficiently, the ergonomic aspect of tools has to be studied [11]. Sometimes, the ergonomic aspect is neglected by software manufacturers and users spend more time manipulating the software than to effectively work with it.

Hence, defining what is a product model means explaining and defining unambiguously *"what design is"* and the answer depends on each author point of view or scientific field.

Another approach for creating an efficient product model is to experiment directly available tools. Then, several cases studies have been lead [3][12][13][14][15] in order to find the best way commercial software should be used at their best. The problem is that models, presented in these studies, can hardly be generalized and then applied to another type of industry. Finally, studies presenting the most advanced product model operational but dedicated for specific field are [16] for steel cast parts, [17] for stamped parts and [4] for complex system design.

1.2. Context of the work

The only point on which every author agreed is that the design process can be represented and leaded thank to a scheme analogous to *object oriented* model. The main characteristics of these objects are state (variable) and behavior (methods) and properties are modularity, encapsulation and instantiations. Additionally, the analysis of the state of the art of design process above shows that efforts are always made on the relations between those four following entities: actors, data, tools and tasks. Therefore, the main purpose of this paper is to present a design for casting product model based on both object oriented approach and interacting entities. Section 2, presents basics of the

product model. Section 3 analyses advances for foundry industry relatively to previous approach based on model analyses.

2. Product model dedicated to foundry industry (PMFI)

The PMFI can be seen (Figure 1) as a system that work in a concurrent engineering context. According to each point of view design actors handle data through various procedures, accomplished either by computers or by human, and thank to several models. The four entities presented in section 1 are recurring except the tools which are, indeed a singular way to combine tasks.

The part of the problem to be solved by the machine uses whatever appropriate techniques: data bases, knowledge based systems, formal solver, information retrieval systems, etc.... The part of the problem that is solved by the human being uses a framework to aid the human being in managing the stored knowledge: mainly information retrieval. The PMFI is then used to integrate the formal (used by the machine) and informal (used by the human being) knowledge representations.

It is important to stress the will to keep human based activities because several strategic decisions are often difficult to formalize and can only be made by a human.

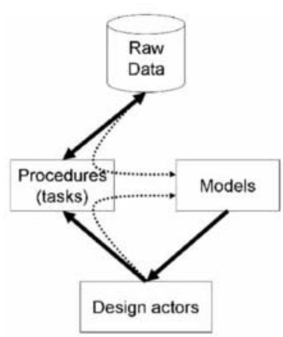

Figure 1.
Layout of the product model

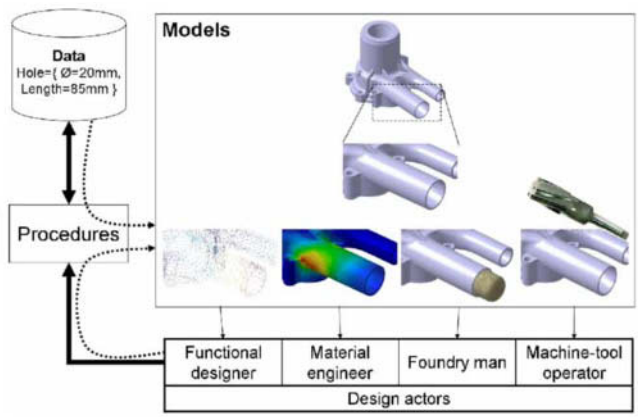

Figure 2.
Example of various models according design actor point of view

2.1. Raw Data

Raw data are the elementary information needed for the design. They can be of any type: boolean, integer float time but also more complex string, table…Data can be directly accessible for design actors but they are always manipulated by procedure for model creation or simulation purpose. For example material data base such as the one following can be directly accessed but are directly exploited by solvers preprocessor subroutines.

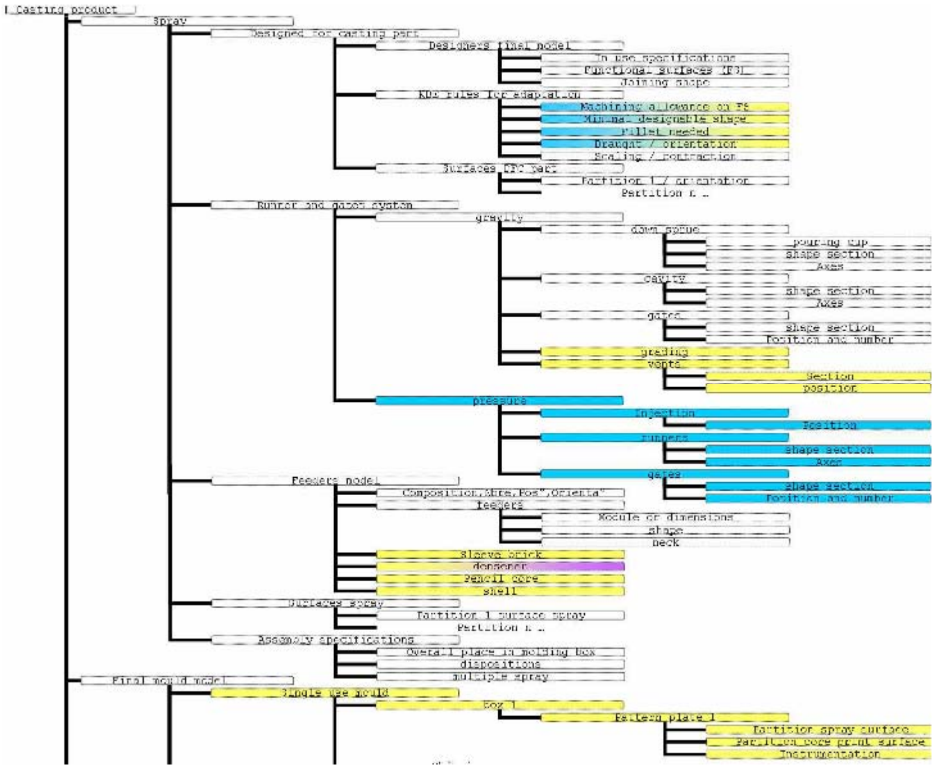

Figure 3. Tree-view of raw data model

Raw data can also be transparently gathered by procedure in order to generate a model. In this case, raw data is not accessed directly by design actors but they have to be recorded as well. By example, in order to represent solid part deviation for the user, the field of internal stress has to be computed and stored before.

In order to improve global consistency among raw data, it is possible to organize data in an object-tree like structure (Figure 3). The tree representation allows using the encapsulation, inheritance or recursive mechanism.

2.2. Procedures

Procedures in the PMFI are group of elementary tasks triggered or done by design actors and that make evolve the product. These procedures aim at several goal:

- Creating a straight thru way to show data (converting data into models)
- Converting design actors will into modifications on (or creation of) data
- Internally create new data from the existing ones.

Theses tasks need classification, aggregation and generalization/specialization throughout the process to enhance abstraction and reuse capabilities. A significant way to improve design process is to give answer to some simple questions: how to develop new and more efficient sub-procedures? And how to integrate these in the framework

described above? This modular aspect (Figure 6) can be provided by object-oriented programming functions thanks to encapsulation mechanism.

2.3. Models

Concerning models, geometry is universally recognized as one of the best medium of communication between design actors. Nevertheless, if shapes are seen identically by all actors, they are observed in a different way. For example (Figure 2) simple tube with a given diameter and length in a part will be considered:

- from fluid dynamics point of view : dimensioned thank to a criterion of maximum flow allowed
- This is here, according to the general specifications of the product, its primary function except it presents constraints for the rest of the product:
- from mechanical point of view : it is a shape dimensioned according to strain, deformation induced.
- -from the process point of view, as a shape that will need extra core in the mould for the rough cast
- and extra deburring or resurfacing operations for end-machining

Semantic considerations attached to raw data vary, according to the point of view. Each one of the design actors cited there above produce his own model adapted to his needs from the two elementary information of diameter and length. That is why this semantic had to be attached to geometry.

3. Advances of the PMFI

Before this study on the product model and in order to identify the model flow problems and the compatibility issues, complete case studies were carried out [3], providing a view on the consistency problems in casting process design. This section explains, through the new PMFI point of view, how analysis of these case studies, made month ago, was in fact the "Model" part of the PMFI.

All stages from the functional design to the casting manufacturing were carried out. The models were generated by three chosen software in order to trim down software compatibility and communication problems, instead of reprogramming a whole environment such as what L Roucoules did in [18] with Open Cascasde [19].

An approach based on model was used: the models identified during the case study can be organized, in a graph structure (Figure 4). In this graph, nodes stand for models and oriented links indicate the chronology of the design process and model flow in the design process. This representation shows that there are two types of problems:

- critical nodes: where there is a chronological link but no model flow link. These nodes break the continuity and the traceability of the CAD/CAM methodology. Improvements in the way that models are treated or transferred at these critical stages are to be proposed.
- lack of consistency: models are linked only by non-consistent relations meaning that associative property of model manipulation techniques here is not guaranteed.

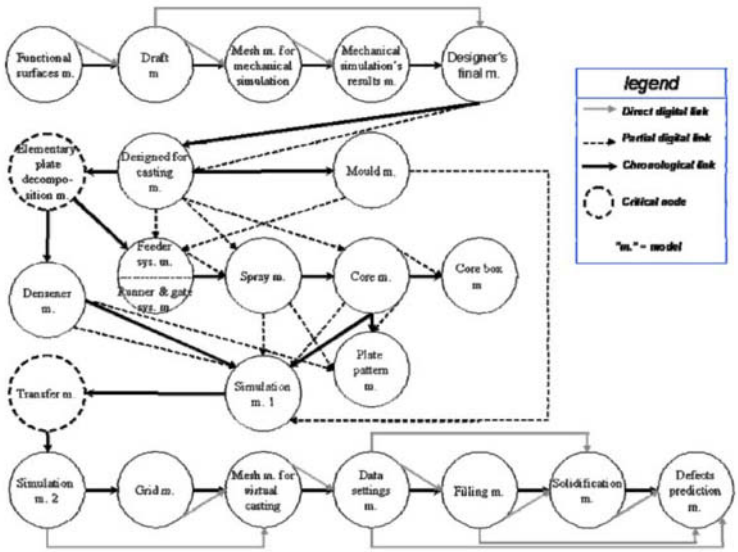

Figure 4. Conception graph for foundry.

The first critical node focuses on feeders design. This is an important phase during the design-for-casting process. As insufficient feeders system lead to defective part, oversized feeders system are expensive and counter productive. Nowadays methodology, used for feeder's system design, needs a manual decomposition of the part in various elementary plates (Figure 5-leftside). Simplified thermal behaviour is given to each elementary plate and the whole behaviour of the part is deducted. Not only this method is time consuming, the major problem of it is that the decomposition is indeed manual. Thus it prevents any integration inside a whole design environment.

A new procedure has been proposed [2], in order to overcome this problem. It mainly deals with a new rapid simulation of the solidification, thank to a simplified model (Figure 5 - right side) allowing localizing hot spot ides zone of the part that need feeders and their size. The advantage of the new approach is that it can be fully integrated inside a standard CAD/CAM environment.

According to PMFI approach, the upgrade can be simply implemented thank to the modular capabilities allowed by object-oriented formalism. It is simply a replacement of tasks under the design feeders procedure and corresponding models. In object oriented language, this upgrade is called an overhead. The specificity here is that former tasks were accomplished manually out of any software. The PMFI formalism can handle manual and numerical procedures: Figure 6 shows the same task accomplished either by human or by computer.

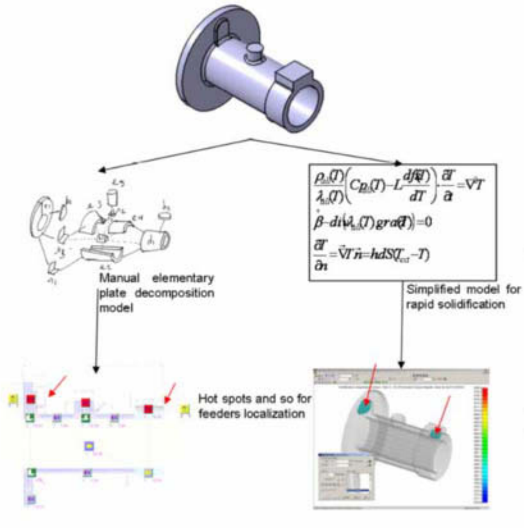

Figure 5. Model substitution

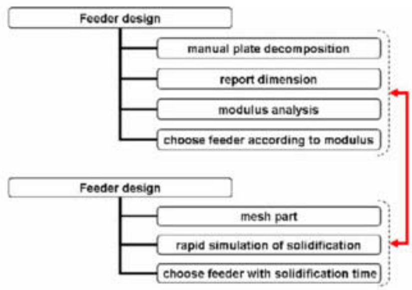

Figure 6. Procedure's upgrade

That was for the first type of problem. The second problem "lack of consistency" of several model could not find a solution with an approach only based on models. This is where PMFI approach occurs: a significant way to ensure associativity between models is to hierarchically self-organize data according to a tree representation. The consistency of data allows to implicitly updating models. As an example (Figure 3 - upper part) the modification of the material will change the contraction coefficient and consequently the design for casting part and the spray model although not the designer's final model. The modification of functional surface will change the designer final model and the two others. Alternatively, the fact to choose an investment casting process disables all part of the graph that are not useful in this case. The tree view of data will then also draw a frame work for design

Conclusion

Previous studies show two types of problems in the design process for the foundry industry: critical nodes and inconsistent transitions. A new approach based on rapid simulation was used to overcome the first major "critical node" problem but the second type of problem needs to rethink the overall organization of data to ensure consistent manipulations. This re-organization is made thank to a so-called product model.

State of the art of different integrated approach using such organization shows that advances were made either on general considerations unrelated to the real world, either dedicated tools hardly extendable to other industry fields.

This paper starts to fill the gap between these two extrema with a new representation of the design process model. This model provides support for object oriented design and is based on the four entities intervening in concurrent engineering context. It ensures data consistency, tasks modularity and then upgradeability. It also provides a non chronologically based framework for design actors. However, if the

feeders design phase has been programmed succesfully[3], the whole product model has not yet been implemented.

Future perspective for the product model is the realization of a software prototype handling automatic feeder design, filling system design and the surface automatic partition for tools creation keeping always consistency. The evaluation and usability of the PMFI will then be possible.

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Transmission systems design – decisions, multi-criteria optimization in distributed environment

Jerzy POKOJSKI [a,1], Krzysztof NIEDZIÓŁKA [a]
[a] *Institute of Machine Design Fundamentals, Warsaw University of Technology, Warsaw, Poland*

ABSTRACT: The paper presents the concept of an environment for computer support of transmission systems design equipped with the multi-criteria optimization module. The environment is limited to the class of structural problems typical for car transmission systems. The proposed architecture is based on object oriented model of multi-criteria optimization problem.

Keywords: multi-criteria optimization, large design problems, distributed design

Introduction

The work deals with problems of decision making and their computer support in industrial design practice.

Computer environments which support the design process of a certain product have been built for many years. The developed applications refer to complete design processes or only to their parts. But the basic goal of either software is its aim to shorten the design process by partial or total automation [2, 12].

At the same time it can be observed that the design works are becoming more and more complex and that they contain more and more modeled engineer's knowledge [2, 8, 9].

Additionally, the degree of difficulty of the design tasks is growing.

In spite of the fact that the importance of computer tools is increasing, the role of the human, i.e. the designer remains crucial and he has to adjust to the changing requirements [8, 9, 10]. The most popular strategy which engineers apply for that purpose is to make step by step amendments with already existing design products and to analyze the resulting effects. It depends on the designer's knowledge how the changes are done. Every designer has his personal preferences which come from his previous experience and his actual knowledge. However, not everything the designer knows is fully articulated. A large part of the information exists implicitly and becomes obvious only when he works on a certain problem. It is quite a big challenge to create a fast and effective model generation of a product. Equally important is its evaluation, the implementation of changes and the current management of the appearing design information.

[1] Corresponding Author: Jerzy POKOJSKI, 02-524 Warsaw, Narbutta 84, Poland; E-mail: jerzy.pokojski@sime.pw.edu.pl

Nowadays design processes are supported by a wide range of computer tools. They have the task of supporting the process generating the model of the product and making decisions for the designer. Tools which are able to support the decision process in design belong to the group of multi-criteria optimization methods.

Today's systems supporting design works are developing a bigger universality. The optimizing modules integrated with them must follow. Moreover, works in distributed design have to be taken into consideration by software which supports certain design processes as well as by software which supports decision problems.

The article concerns a concept for a system supporting the design process of vehicle transmission systems. It bases on a class of structural solutions and considers the above conditions.

1. Multi-criteria optimization in engineering design

In every design process decisions are made constantly [7 –11]. In establishing the design process for an actually realized project the engineer first defines his detailed steps for that task. Mostly the process is built up gradually together with the development of the project. First of all the sequence of planned tasks is fixed. Then they are realized, whereby the different stages are outcomes of the results of earlier ones. After that corrections are made requiring a repetition of certain steps after the evaluation. Sometimes new and different stages are provoked by the rejection of earlier results. The parallel evaluation of the project results has a strong impact on the sequence of the tasks that have to be realized.

Practice shows that the designer very often uses the maze model for his work [8-9]. But the maze is only a metaphor. It explains the potential possibilities the designer has at hand while working. In spite of that analysis of the structure of realized design tasks revealed that there is a certain dependence on the maze model. Another feature of the decision making process is the fact that certain activities which are parts of the maze repeat themselves several times. So we have an iteration process which improves a solution.

This process creates the next generation of new variants of a solution on the bases of knowledge and also conclusions on the basis of results which have been obtained in the iterations up to now. But it may also be a unique generation of many variants which are compared to each other at the same time and have to be sorted out. The problem which occurs in this case may be characterized as a multi-criteria optimization task [1, 3, 5].

When analyzing various design processes it becomes obvious that each of them contains tasks which can be defined in the above way as multi-criteria optimization tasks. Some of them reappear in sequences, others can be realized parallel during the process whereby the tasks sometimes belong to different disciplines. In both cases the tasks can be formally connected to each other, which as a consequence effects the quality of the gained solutions. It is possible to treat several of those tasks as a total, that means as one multi-criteria optimization task. But to get the optimum for that total, the whole procedure has to be repeated again in the form of integrated problems. This is a standard conventional approach applied to these types of problems. However, we have to make sure that the above situation occurs only with well defined problems

which do not involve any uncertainties. In literature we often find examples modeled in MDO (Multi-Discipline Optimization) which refer to such a situation [4].

The numerous design tasks which we encounter in industry have many of the elements mentioned above occurring simultaneously. The design process, respectively as its detailed instance, is built in the course of its realization. Unforeseen design activities are added and others lose their importance. Some steps are carried out iteratively, whereby the iterations can have a multi-variant character. As a consequence we acquire tasks which are typical for MDO approaches. As it is difficult to capture and formulate their knowledge chunks, and because of their uncertain knowledge these tasks lead to a repeated analyses of the value parameters of the whole problem.

2. Knowledge in engineering design

When looking at the design process as a sequence of activities we can assume that all sorts of activities are selected by the designer and carried out one after the other [8, 9]. Each activity contains its knowledge sources on which it is based. In general the knowledge is connected to a concrete person of the respective project and does not always necessarily have the same form. Every actualization of an activity may cause knowledge modifications for the given activity.

The designer's knowledge can lead to a certain inference on the bases of which he aims at finding the best possible solution according to his opinion. But it is not excluded that his inference results in a situation where the possessed knowledge generates multitudinous solutions. The knowledge a designer obtains does not facilitate a qualitative simple solution. And exactly at this moment the method of multi-criteria optimization finds its use.

The solutions which have been presented up to now show that the environment supporting decision processes in machine design should take into consideration the many discussions made on the bases of constantly evolving knowledge. Additionally, at certain stages it is possible to apply the method of multi-criteria optimization. As a consequence we gain quite associated structures which make tasks suitably representative for MDO. Moreover, the process is iterative and generates numerous chunks of small and medium sized results.

Unfortunately, it is not an easy undertaking to build a universal environment providing the possibilities laid out above; not only with respect to the programming conditions. According to the author's opinion it is also very important to be familiar with the concrete history of a design process from the perspective of its creator. The following chapter presents two exemplary implementations.

3. Computer support of transmission systems design

The two examples of environments presented here contain both the problem of knowledge storing and the modeling of multi-criteria tasks together with the data management.

The first example [6, 8, 9] deals with an application that supports the design process of a car gear box (Fig. 1A). The gear box has a given structure. In the following it is assumed that each calculation is done for a gear box with the same

structure. The calculation process sets out with the choice of the initial decision variables for each pair of wheels, the intervals of their variability and the definition of the constraints and the objective criteria. Next, each single gear of the given gear box variant is calculated with the help of the optimization module. During the calculation it is possible to check whether the variant in question is correct and to optimize it in case of need. The calculation results are stored in the data base and depicted in the task's history tree. Information about the goal of the actual calculation can be added to each calculation variant of the gear box. On the bases of the knowledge implemented in the system certain comments are also automatically generated. The user then collects knowledge and puts the realized instances of optimized tasks into the archives. The second part of the system is an application in the CAD system in which the geometric 3D model of the complete gear box is built. The shafts and the bearings are modeled in the classical way, whereas for the tooth wheels and the clutches Knowledge Based Engineering is applied. Each calculated variant of the gear box can be generated as a geometric model. Hereby the modeled knowledge, which generates the geometric model, also contains elements which generate objects as well as elements which verify whether the obtained geometric relationships are correct.

The modeled design process enables the user to store the design knowledge as notes, as comments or as knowledge implemented in a KBE approach and authorizes him to define multi-criteria optimization tasks. Additionally, initial as well as final information can be stored and managed. At this moment the management of geometric information is ignored as it can quickly be created automatically when needed.

The concept explained here arose from project assumptions. With the environment various cases were built very effectively. The structure of the gear box, however, was to be left unchanged and its case remained always the same.

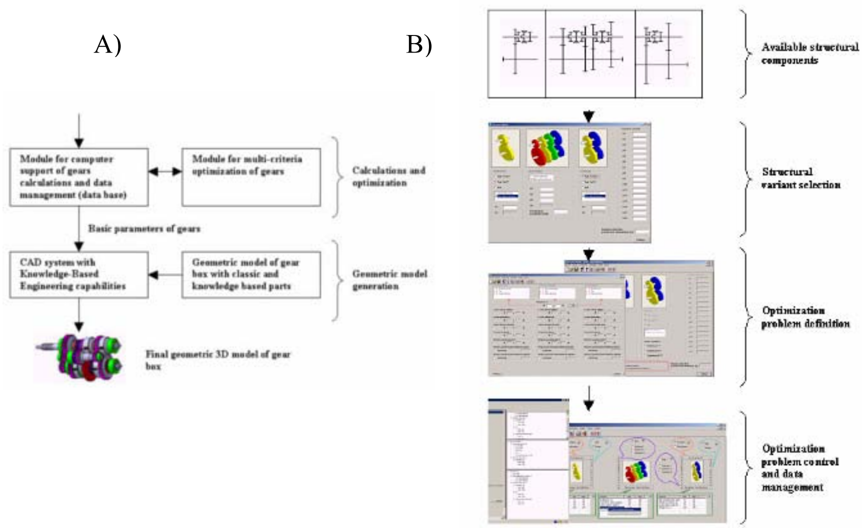

Figure 1. Structure of first (A) and second (B) exemplary application.

The second example [11] is the broadening of the first part of the first example (Fig. 1B). It focuses exclusively on the items of calculation and optimization, but the problem is not restricted to a single gear box. It takes into consideration various truck gear boxes [11]. The application wants to foster the modeling and solving of

miscellaneous optimization tasks. It refers to specific gear boxes for a concrete transmission system and also to tasks which are compiled of optimization tasks that are defined for several boxes of a given transmission system at a time. With the computer system the history of the calculation and the management of the already realized tasks can be stored in the data base.

The established environment serves quite effectively the creating and solving of optimization tasks for a specific transmission system. This is especially meaningful when transmission systems are designed for trucks which are used in different geographic regions. The application can relatively easily be equipped with KBE models and a generator for geometric 3D models.

4. Concept of flexible and distributed environment for the support of transmission systems design

The examples presented in the chapter above deal with applications that support the design process of transmission systems for vehicles under of considerably strong structural limitations. In the first case the application is made only for one scheme of a designed gear box. The second task comprises three gear boxes which cooperate with each other and have given structures. It is possible to disregard the analyses or optimization process of any of the boxes while designing them. The structural restrictions which are mentioned significantly limit the application of the implemented software. When we consider how much effort has been put into that work (applying such tools like MS Visual Basic, version 6 and NET, data bases, CAD systems) we must come to the conclusion that it is uneconomical to build an application for such a narrow field.

We try to approach the problem with the eyes of a potential software user. Probably a more interesting system for him would be one which has different structural types of transmission systems for different kinds of vehicles modeled. Such a system would also have to ensure the creation of a transmission system model with transmission for 2 or 4 wheels independent of the varying degree of accuracy of the accepted solutions. Consequently, the system should offer tools which can help to create graphic models (schemes of transmission systems) of the vehicles' transmission system.

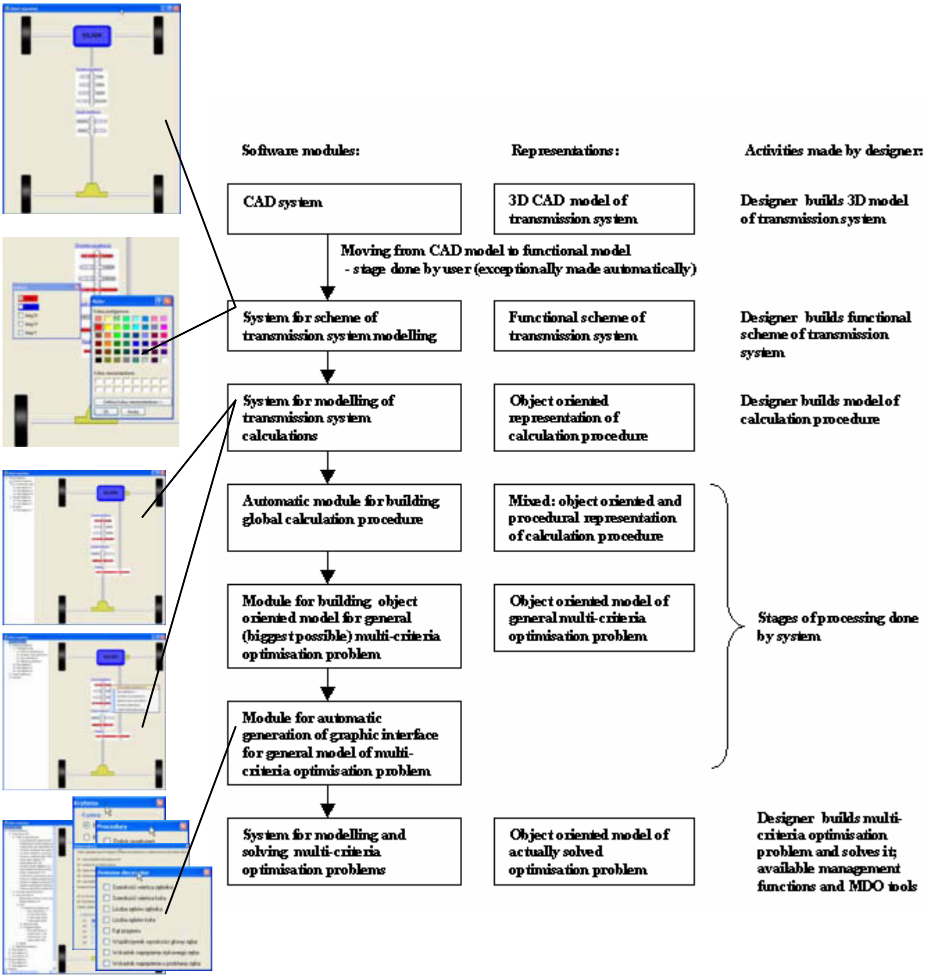

Figure 2. Concept of system for computer support of transmission systems design.

In this case we have to start with the establishment of an object oriented compilation of elements that occur in the respective class of transmission systems (Fig. 2). The special objects should have their graphic representations so that the scheme of the transmission system can be shown in a 2D picture. Such a model emphasizes the kinematics and dynamics connections between the elements of the modeled transmission system. It is possible to build procedures with which global kinematics calculations and strength calculations for the complete modeled transmission system can be performed. As a rule this type of calculation gives many combinations of acceptable results. Because of that we can try to apply the multi-criteria optimization method. However, the basic drawback of such a task is its fast modeling, that means the fast selection of decision variables, constraints and criteria. This task itself may extend to quite a big size.

After the modeling of the transmission system scheme, the computer system automatically builds an object oriented model of the multi-criteria optimization task. It is the biggest and most complex task that can be realized for a defined scheme of the transmission system. This process happens automatically on the basis of the implemented knowledge model. The object oriented model of the optimization task of the transmission system can then immediately be transferred to its own graphic interface. At that point in time the designer has the opportunity to model different decision tasks and follow with their solutions.

With this approach the authors of this concept want to achieve an effect which comes closest to the one which was obtained in the second example of the previous chapter and which is valid for various structures of transmission systems.

Obviously the previous application had much more limited structural possibilities. Nevertheless, the interface of the optimization task reacted on changes in the model of the transmission system. Even the data structures applied in the system kept up with the decisions.

When we consulted the above concept with people involved with the designing of transmission systems we noticed a very strong specialization among the engineers. So we had to discuss the project with many experts coming from very specific task areas (such as viscotic clutches, manufacturing capabilities of existing machines, possibilities of electronic control systems)

This observation stimulated us to improve our concept with a module that automatically generates an interface for the cooperation with external software modules (for the respective structural scheme of the transmission system) which resulted in an optimization task model. The interface is meant to organize the cooperation in the net's environment. It has to make sure that other modules from other computers which belong to other specialists and are developed and serviced by them are integrated with our system in time for doing the calculation and optimization of the transmission system. The integrated modules can be different applications, from elementary calculation programs to systems belonging to the KBE class. One example of that kind of cooperation represents the generation of the geometric 3D model of the gear box in the first exemplary application of the previous chapter. It is assumed that the designer does the calculations in the same way as in the case of the calculation and optimization application. After that the basic data are sent to the persons who build KBE applications. Doing so, many dependencies on the forming of specific elements of the box are ignored and the generation of the 3D model of the box is carried within the control of the application.

The application described in the work is being realized at the moment. The authors have built and considered some solutions of the earlier version of the application (in the second example of the previous chapter). Most of them belong to the elements from the object oriented models of the transmission system and multi-criteria optimization tasks. As a total the application is expanded. Another very serious problem is the improvement of the quality of the calculation module in the system. The authors have won A. Wąsiewski ([11]) as a cooperator. At present the authors are busy with the adaptation and establishment of a classical software by A. Wąsiewski. It shall support the design process of elements for car transmission systems (with regard to the above concept of system building) and integrates the above conception for building the system.

5. Conclusions

The proposed approach strives to eliminate shortcomings which arise with previously developed applications. The main goal is to create a more universal approach. This premise is realized by making the analyses of a bigger variety of transmission system structures possible. The approach exploits very advanced calculation modules together with an increased automation in the process of modeling multi-criteria optimization tasks. The option of introducing the system application for cooperation into a distributed environment is also taken into account. In the light of the advanced concept presented in this work the two previous examples reflect only instances of the newly built environment (in the nomenclature of object oriented modeling).

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An Object Oriented Extensible Architecture for Multi-Level Systems Analysis

Gregory J. Follen[1], Russell W. Claus[1], Scott Townsend[1]
[1]NASA Glenn Research Center, Cleveland, Ohio

Abstract. This paper discusses the salient features of the NPSS Architecture including its interface layer, object layer, implementation for accessing legacy codes, numerical zooming infrastructure and its computing layer. The computing layer focuses on the use and deployment of propulsion simulations on parallel and distributed computing platforms. Features of the NPSS architecture include support for Multi-Disciplinary (MD) Coupling, Computer Aided Design (CAD) access and MD coupling objects.

Keywords: Software architecture, System Simulation, Concurrent Design.

Introduction

Today, propulsion engineers use preliminary and conceptual design codes to numerically create and analyze commercial, military and rocket propulsion systems. Most of these computer codes were written in the 60's and 70's and many, if not all, are written in FORTRAN. For some time now, analyzing and building propulsion systems has been prohibitively expensive due largely to the iterative nature of designing, analyzing and testing of hardware before a final configuration is achieved. In order to reduce cost, risk, time to market, expand capability, assure accuracy to mission requirements and increase confidence in designs, innovative ways have to be found to numerically create propulsion systems that bring the design closer to the final configuration before hardware is ever built and tested.

The NASA Glenn led Numerical Propulsion System Simulation (NPSS) is a project targeted at impacting this need. NPSS was created to advance the state of the art in propulsion modeling and create a common architecture to numerically model any system [1]. NPSS benefits from the rapidly evolving parallel and distributed computing platforms that enable increasingly challenging software simulations and from its object oriented design.

1. NPSS

The current state of the art in propulsion modeling centers on the use of 0 Dimensional preliminary and conceptual design methodology. However, NPSS wanted to look beyond the current ways propulsion systems were designed and created. NPSS dreamed of a system that allowed an engineer the flexibility to numerically assemble an

engine using 3-Dimensional components or any combination of 0,1,2,3 Dimensional component codes. The "plug-n-play" or "substitute at will" concept captures the essence of this goal. Figure 1 embodies this concept.

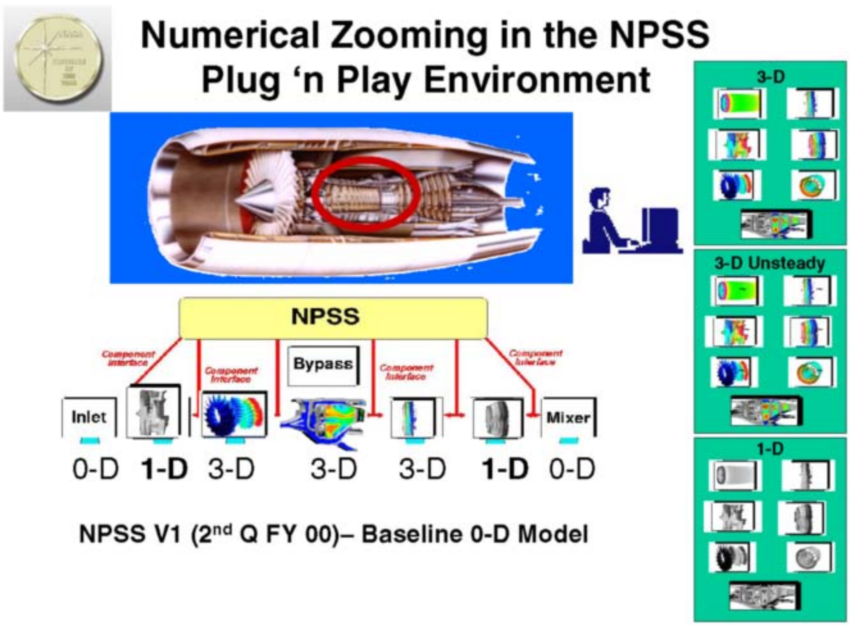

Figure 1. Conceptual diagram of the NPSS environment.

With this in mind, an object-oriented architecture was designed and laid out to fulfill this vision. The NPSS object-oriented architecture allows an engineer to numerically assemble a propulsion system comprised of differing dimensionality component codes (Numerical Zooming), different disciplines (MD coupling), all irrespective of the computing platforms these codes execute on while producing results on cost effective computing platforms overnight. A product of the NPSS Architecture is NPSS V1.0 [2]. NPSS V1.0 preserves the traditional preliminary and conceptual design methodology for designing engines that is the state of the art today, but it also moves the state of the art in propulsion system modeling into the future. NPSS V1.0 is an object oriented preliminary and conceptual design code used by aerospace engineers to predict and analyze the aero-thermodynamic behavior of commercial jet aircraft, military, and rocket engines. However, it is more than this. NPSS V1.0 has designed into it the infrastructure supporting Numerical Zooming to higher dimension codes and coupling to differing discipline analysis. As the state of the art in propulsion modeling moves into the future away from a strict adherence to 0 Dimensional analyses towards a mixture of 0,1,2,3 Dimensional codes, the same NPSS' architecture exists to support this maturity in modeling.

The NPSS architecture is pictorially represented by figure 2. The architecture is open and extensible. To this end, the architecture exploits the capabilities of object-

oriented programming (inheritance, polymorphism, and encapsulation) as well as modern object-oriented concepts including frameworks, component objects, and distributed object standards.

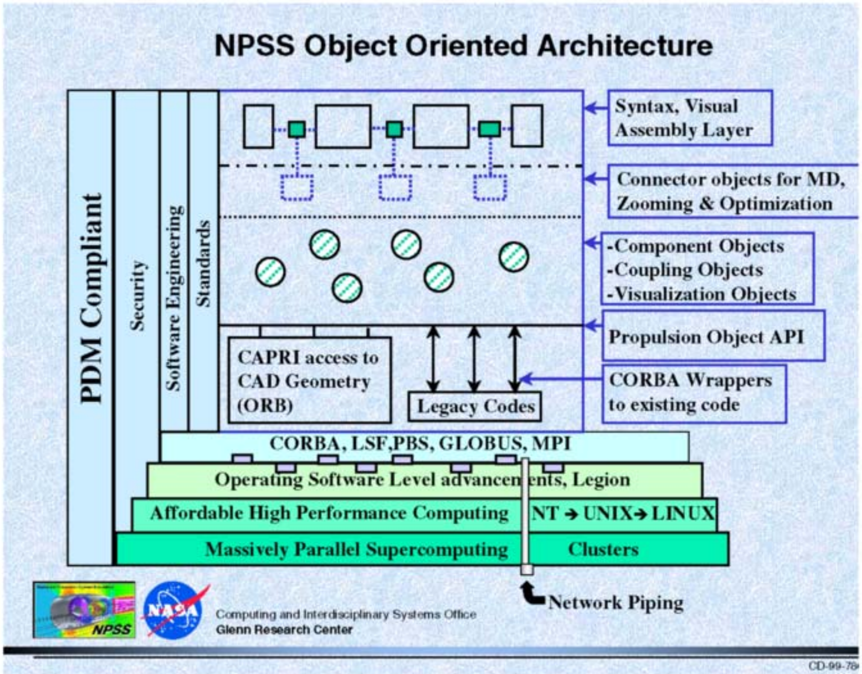

Figure 2. Software framework for systems analysis.

2. Design Philosophy

The NPSS Architecture was designed following a hybrid object oriented design philosophy. The early work by I. Jacobson and G. Booch were followed where appropriate and extended by experiences known within the NASA culture[3]. An overall philosophy for NPSS was to view the architecture from a leap-frogging approach, purchase from the commercial sector what you could and build from scratch what you must. The project benefited from new and innovative hardware or software that was incorporated into the architecture as quickly as possible without a huge development effort and without disturbing the quality and stability of the current system. To make the advances in propulsion design, time could not be wasted on re-checking answers, re-writing code and re-designing entire sections of the architecture. This was the fundamental reason the object-oriented paradigm was chosen. Beliefs then, and proven now, demonstrate that the object oriented design methodology was a critical factor in the development of a flexible architecture.

3. NPSS Architecture

Referring to figure 2. above, there are fundamentally three main areas of the architecture. These are: the Interface Layer, Object Layer and the Computing Layer [4]. Within the Interface Layer, a command-line and a visual interface exist. The Object Layer contains the fundamental engineering specifics for propulsion systems and the appropriate support objects needed by propulsion systems such as access to geometry and legacy FORTRAN codes used by many, if not all, propulsion companies. Last but not least, the Computing Layer exists on which to deploy propulsion system simulations. This last layer, Computing, is and has been the most dynamic over the last ten years and continues to change about every 18-24 months.

3.1. Interface Layer

From the beginning of the architectures' development, the priorities were to get the engineering and physics right and then add a visual interface later. Given this, the main interface to NPSS has been a command line. However, do not assume that this is a simplistic interface to NPSS. On the contrary, the command line and its suite of syntax are quite elegant, mature and sophisticated. Two versions of the command interface exist:

Batch: npss [-*options*]file1 *file2* . . .

Interactive: npss [-i][-*trace*][-*options*]file1 *file2* . . .

Contained within the file1 is the actual NPSS syntax that defines the propulsion system to be designed and analyzed. The language used here is C++ like but not pure C++. Early exposure to pure C++ as the syntax changed the direction to create an interpreted C++ like syntax. This change allowed an easier and early adoption of NPSS. While most engineers wanted a FORTRAN language, many of the concepts envisioned fell victim to FORTRAN's language syntax. The syntax itself has many features of a programming language and indeed, a feature we've added is an NPSS syntax to C++ converter. This feature allows code first developed with the syntax to be later compiled as part of an executable library available for later use. _Productivity increases using interpreted components, because the source code need not be rebuilt. NPSS parses the interpreted components and executes the model. After the components have been developed interpretively, the engineer may choose to build the components as internal objects or dynamically loadable objects. A sample of the syntax looks like the following.

```
Model BWB {
    Element FlightConditions AMB0 {. . .}
    Element Inlet Inlet {. . .}
    Element Fan Fan{…}
    Element Compressor Compressor{..}
    Element Combustor Combustor{…}
    Element Turbine Turbine {…}
    Element Nozzle Nozzle(…}
    linkPorts ("FlightConditions.Outlet", "INLET.F1_I", "FL0",……);
}
```

The syntax has programming constructs such as the ability to declare new variables that are combinations of other variables, comments, If-then-else, do while's, arithmetic functions: *, /, +, -, exponentiation, logicals, >, <, =,...., etc.

The visual front end (i.e. graphical user interface) communicates with the NPSS system through the command interface as just described. A view of this interface is shown in figure 3. Visually speaking, NPSS provides the ability to assemble and connect a propulsion system together and then execute this simulation as well as store or archive it as necessary. It is the author's belief that in order to maintain flexibility, maturity of NPSS and advancement to its capabilities, a visual interface and a command interface must always exist separately. Once the visual interface becomes part of a code, a violation to the integrity of the original intent of the code has occurred and can never be recovered. As future interfaces emerge such as voice activation, screen sensing and even optical movement or heads up displays, in order to break from the current visual interface and make use of the futuristic interfaces, a command interface will need to exist.

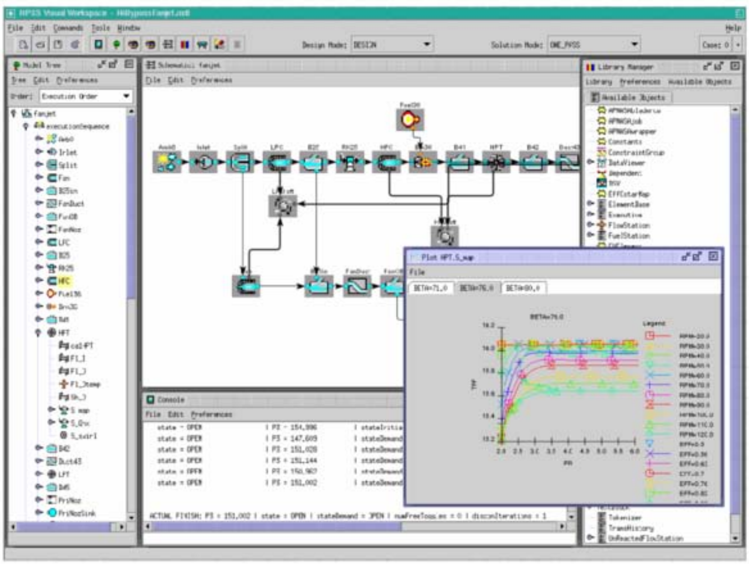

Figure 3. Visual interface for NPSS.

The NPSS framework makes extensive use of object-oriented programming principals. The primary systems analysis that uses component maps to model component behavior (so called zero or one dimension) is written in C++ with a clear modular structure. For calculations requiring distributed / parallel processing, Common Object Request Broker Architecture (CORBA) is used. CORBA is an object-oriented framework that uses Interface Definition Language (IDL) to define clear interface(s) between remote or local objects [5]. It is typically used to unite a complete system simulation (low computational demand) with a more detailed simulation of a single component or sub-system that uses extensive computing resources. Research has been conducted in this area to mask that fact that objects are remote or local. That

is to say, objects can be treated as if they are always local but in reality they may be on distributed computing platforms [6].

3.2 Object Layer

NASA Glenn has populated this layer with airbreathing, rocket and to a lesser extent ground based power objects. What is marquee about this architecture is that the infrastructure contained within the NPSS syntax is the same for airbreathing, rocket and ground based power objects. While the NASA Glenn led team came together to define what a common set of airbreathing, rocket and ground based power objects are and defined their numeric behavior, this does not mean that the objects' behavior and characteristics cannot be changed on demand. On the contrary, the ability to change or extend the objects behavior is central to the use of the object-oriented paradigm. The objects provided can be used as they are or can be changed based upon appropriate need. Additionally, the developer is assured that the object has been tested and proven to be accurate. So, any abnormal behavior is due solely to the new features just introduced by the developer. The basic objects used within the NPSS Architecture for 0 Dimensional and 1 Dimensional analysis are:

•Elements
–Primary building blocks connected together via Ports
–Perform high-level calculations
•Subelements
–Interchangeable secondary building blocks that plug into Elements or other Subelements
–Perform detailed calculations
•Flow Stations
–Responsible for thermodynamic and continuity calculations
–Access the thermodynamic packages
•Ports
–Used to connect Elements together
–Five types (Mechanical, Fluid, Fuel, Thermal, Data)
–Directional in nature (i.e., outputs connect to inputs)
•Tables
–Organized set of numbers that relate n-dimensional inputs to one or more outputs
–Support linear and second or third order LaGrange interpolation
–Support fixed value end-points or extrapolation (linear/2nd/3rd order LaGrange)
–May be used at any location a function is called and vice-versa

Of particular note in this object definition, is that there isn't a reference to anything related to propulsion. The NPSS Architecture's object structure, as defined, has allowed its general usage amongst airbreathing, rocket, fuel cell and ground based power propulsion by the writing of the appropriate functional objects. The author believes there are more applications to come.

3.3. Computing Layer

The basic internal communication scheme used by the NPSS Architecture for moving data across address spaces and separate machines is through its CORBA interface [7]. This is a point-to-point concept of distributed computing and coupling of codes. Leveraging CORBA and its associated Security (CORBASec) software has proven quite useful. The NPSS Architecture makes an assumption that any 3 Dimensional Computational Fluid Dynamics (CFD) code has already been parallelized or can be deployed with a batch scheduler. For NPSS' needs, the Grid Computing software GLOBUS, needed to be aware of CORBA based simulations The NPSS team has developed a CORBA interface to the GLOBUS services to support the NPSS Architecture[9]. The project goal has been to deploy complex propulsion simulations that can be solved in an overnight timeframe in less than fifteen hours on cost effective computing platforms. The corresponding Architecture goal is to deploy these subject simulations on any computing cluster with minimal to no changes to the codes.

NASA Glenn's participation in the development of parallel computers and networks focused on cost effective clusters. Originally, a thirty-two node cluster of IBM 590's with multiple networks was assembled from commercially available UNIX machines. Following cluster's included a 128 node Pentium PC cluster comprised of 64 dual processor Pentium 400 Mhz systems running LINUX. Both these systems were batch oriented with the resources controlled by Platform Computing's Load Sharing Facility (LSF). Today, different flavors of PC based clusters have been built. The latest of these is 170 node G5 cluster used for aero-propulsion simulations.

3.4. Code Integration, Multi-Discipline Coupling

A key aspect of the NPSS architecture is the development of Application Programming Interfaces (APIs) that permit the integration of multiple analysis codes [10, 11]. There are three main elements of this task. First, the analysis codes must be made accessible to the rest of the NPSS system. Where the coupling between codes is 'loose', or not performance critical, an instance of NPSS can be used to 'wrap' the code by writing input file(s) and parsing output file(s). This method of code wrapping requires no changes to the analysis code. In situations where 'tight' coupling is required, such as a coupled unsteady 3D CFD calculation, then the analysis code uses an API in NPSS that gives the code an NPSS CORBA interface. Second, a set of objects were created to permit data flow between different analyses. These data flow objects include scalar and array variable objects, structured and unstructured multi-zone grid objects, multi-zone, multi-variable data objects, and metadata objects. These objects provide clear interface standards that enable the integration of disparate computer codes[8]. The third major element in integration is the creation of a common API for geometry. The major Computer Aided Design (CAD) systems provide substantially different representations of geometry. The burden of building complex system models would be impossible, if each analysis had to read different representations of the geometry. Some representation might not be suitable for one type of analysis, while the same representation might be exactly correct for another application. To address this issue, NPSS's design calls for using the Computational Analysis Programming Interface (CAPRI [10,13]) – a common interface for geometry, specifically created to enable application code integration. At the present time, CAPRI is not integrated into the NPSS Architecture or distributed as part of NPSS V1.0.

4. Concluding Remarks

Industry feedback on the benefits of NPSS reveal a 55% reduction in the time to perform engine system simulation throughout the product life cycle[12]. Additionally, expectations include a 50% improvement in business processes with partners and customers. The NPSS Architecture emerged to impact airbreathing propulsion in the ways mentioned above. However, soon after its first incremental release, it was used to impact space propulsion and ground based power. The NPSS architecture was re-used to model rockets, ground based power systems and even fuel cells by populating only a few application specific objects with the remaining architecture being reused. The framework has proven to be quite flexible.

The process by which NPSS was built is noteworthy. Software development combines a production phase with early prototyping. New releases are deployed incrementally. This provides for early access to fixes and new features that ultimately lead to the stated goals of reducing risk and reducing the time to final design.

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An HTN Planning Approach for Power System Scheduling Using SHOP2

Jingge Song, Jianzhong Cha [1]
Beijing Jiaotong University, Beijing, China

Abstract. HTN Planning is an efficient approach in real-world planning problem solving. Operating order synthesis (OOS) is an important application area of AI techniques in power system scheduling in China. An HTN Planning approach is proposed for OOS based on SHOP2 methodology and planner. In this approach, power system model is constructed hierarchically in three levels. Based on different levels of system model, three types of task are identified and task decomposition strategies are proposed respectively. An example is presented and some issues are discussed.

Keywords. HTN planning, Operating order synthesis, SHOP2, system model, task decomposition strategies

Introduction

Operating order is an important assistant to scheduling operator of power system in China. It can help human operator avoiding operating mistakes and improving operating skill. Traditionally, it is written by hand or word processing software. With the development of AI technology, operating order synthesis (OOS) became an important application area of AI in power industry. Task of OOS is to produce an order, actually a scheduling scheme, containing sequence of operation tasks or actions to reach a scheduling goal.

There have been some research and applications in this area [1][2]. These researches are mainly based on production rule-based expert system approach. Rule-based system is simple in knowledge representation and easy to built. But to real-world problem, it is difficult to manage and extend to a large knowledge base because conflict cannot be reduced efficiently.

AI planning is theories and methodologies aims to produce action sequence from an initial state to a goal state. OOS problem can be seen as a planning problem that operating order, a plan, will make power system changing from one operation state to another state. HTN planning is one of the basic approaches of AI planning which is more suitable for large scale and hierarchical tasks real-world problem. In many industrial domains, systems are generally structure-based and related tasks are hierarchical. So in this paper, we discuss an HTN planning-based approach in OOS domain.

[1] Corresponding Author: Jianzhong Cha, Beijing Jiaotong University, Beijing, China, E-mail: jzcha@center.njtu.edu.cn

1. Overview of HTN Planning

HTN (hierarchical task network) Planning is one of the basic types of AI planning which aims to solving real-world planning problem with task decomposition. In many real world application areas, task is easy to describe and achieve. Meanwhile, in some cases, it is hard to give complete and accurate description of goal state. So using goal task as alternative description of goal state is a natural choice.

HTN planning problem instance can be defined as:

$$Inc=<Dom, Prob>$$

Where $Dom=<T, S>$ is HTN domain, T is set of tasks, S is task decomposition strategies. $Prob=<I,G>$ is problem instance, I is initial state of system and G is goal task instance.

HTN planning was primarily proposed by Tate and Sacertodi in 1970's[3][4]. Erol[5] first give an predicate logic-based formal definition and analysis in 1990's. Then Nau[6] give some revises in SHOP2 system. The following are some concepts in SHOP2 mechanism.

Definition 1 (*Operator*) a SHOP2 operator is an expression of the form $(h(\vec{v}), Pre, Del, Add)$, where $h(\vec{v})$ represents a primitive task with a list of input parameters $\vec{v}$.*Pre* represents the operator's preconditions. *Del* represents the operator's delete list which includes the list of things that will become false after operator's execution. *Add* represents the operator's add list which include the list of things that will become true after operator's execution.

Definition 2 (*Method*) a SHOP2 method is an expression of the form $(h(\vec{v}),Pre, T)$,where h is a task name with $\vec{v}$ as input parameters , *Pre* is task's precondition, T is a partially ordered list of subtasks which consist the decomposition of $h((\vec{v})$.

Definition 3 (*Planning Problem*) a planning problem for SHOP2 is a triple (S,T,D),where S is initial state, T is a task list, and D is a domain description, By taking (S,T,D)as input, SHOP2 will return a plan $P=(p1p2...pn)$, a sequence of instantiated operators that will achieve T from S in D.

2. HTN Model for Power System Scheduling

2.1. Architecture of Knowledge Model

Generally, knowledge model of intelligent system contents two part, domain description and problem solving strategy. So our architecture also includes two basic parts, system model and HTN model (Figure1). In system model, power system domain is classified as device, sub-system and component hierarchically. Each level can get a simplified description of the system with description reasoning rules. In HTN model, Tasks and operations are identified as four levels, general task, sub-system task, operating task and operating action. Up level tasks can be refined with task decomposition methods.

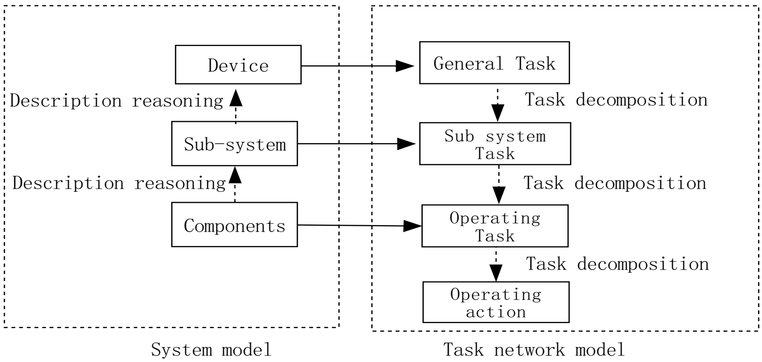

Figure1. Architecture of knowledge model

2.2. System Model

Here we give the following predicate logic-based description mechanism as construction approach for power system modeling.

Definition 4 *Power system model* is a five element tuple as

$$SM=<O, C(o), R(o), S(o), A>$$

Where O is set of system objects, C is type predicate of object, R is relation predicate which indicate relations among different objects. S is state predicate of objects. A is set of axioms that execute description reasoning.

To set of system objects, O can be refined as

$$O=O_D \cup O_{SS} \cup O_{COMP}$$

Where O_D is set of device object, O_{SS} is set of sub-system object and O_{COMP} is component objects.

Device object is identified according to general types of device in power system, including transformer, bus, etc. Sub-system is the refinement of device object that contents topology structure. Component object is basic element of power system that associates with operating action directly.

To make system model easy to understand, description reasoning is introduced with *Axioms* as reasoning rules. Here we introduce two types of axiom, state abstraction and state transformation

- State abstraction — this rules is used to abstract state of component or line in low level to describe sub-system state or device state in a simple and explicit way.
- State transformation — this rules is applied to make some description to some other equal description. For example, if there is no ‘opened (switch1)’, we can infer that there should be ‘closed (switch1)’ as a state description.

2.3. Task Network Model

Definition 5 *Task network model* of power system scheduling is a four element tuple

$$TM=<DT, SST,OT, OP>$$

Where *SWT =(n,o, is, fs)* is device task，*SST =(n,is,fs)* is sub-system task; *OT =(n,o)*is operating task, *OP=(n,o)*is operating action. *n* is name of task, *o* is device object, *is* represent initial state and *fs* is goal state.

Device task is at the top level of HTN, describing different kind of goal task. Generally, goal task can be described as four state switching, including serve, hot reserve, cold reserve and repair state.

Sub-system task is at the next level of device task. It is the refinement of device tasks. There are definite operating objects in sub-system tasks. Each operating object has definite topological structure.

Operating task is at the next level of sub-system level and based on description of component, including some local sequence of operating action. So operating task consists of several operating actions.

2.4. Task Decomposition Strategy

1.Device task decomposition

Actually, decomposition strategy of device task is to search sub-system task, from general four-state switching task to a particular task of sub-system object. This method is a bridge between general task and particular task. Figure 2 show this strategy.

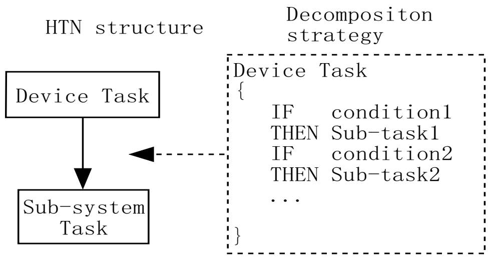

Figure 2. Device task decomposition

This strategy is a set of <IF-THEN> patterns, which aims to located the properties and basic structure of device and task. The form of this strategy is simple and its hierarchical relation from general to detail will construct up level part of HTN.

2. Sub-system task decomposition

Decomposition of sub-system task is to refine state switching task to actual component operating task. Because different sub-system has its own characteristics and functions, the sequence of operating tasks can be seen fixed. But in operation period, according to different system state, some operating task may not be executed, so tasks should be selected based on a fixed order. Here we apply a recursive strategy as Figure 3.

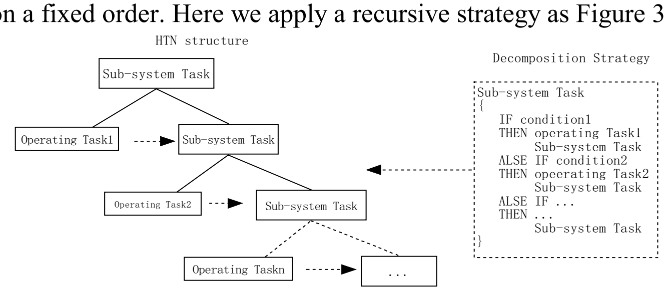

Figure 3. sub-system task decomposition

This strategy is an <IF-THEN-ALSE IF-THEN…> pattern, which aims to form a sequence instance according to current system operation state. This strategy is relatively complex. Its construction needs more knowledge about actual sub-system and experience. But because it focus on specific sub-system, knowledge will not conflict with other strategies in other HTN branch.

3. Operating task decomposition

Operating task is system component oriented task，the operating action in it generally have definite sequence, so it can been instead by using a sequence of operating actions. The mode of decomposition strategy is shown in Figure 4.

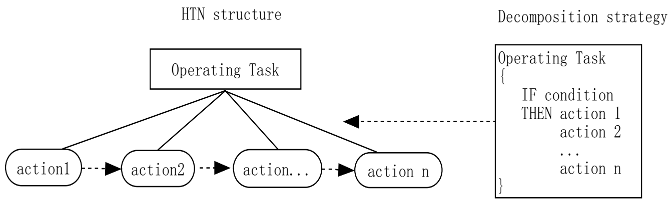

Figure 4. Operating task decomposition

This strategy is only one <IF-THEN> pattern, which aims to refine sub-system task to actual sequence of action on components. To some classical system components, sequence of operating actions is generally the same and is allowed not to change in component operating.

3. Example

3.1. System Prototype

We use a 220kv-bus system as an example to show the use of HTN planning approach to build OOS system knowledge base. In Figure 5, the system instance contents 2 transformers, 3 buses, 1 bypass and 2 lines. Operating objects include switches, fuse, etc.

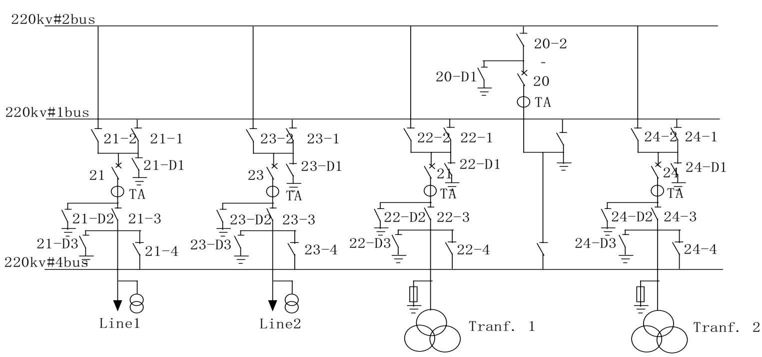

Figure 5. Prototype of a bus system

The system model of this instance consists system objects, hierarchy relation, topology structure and state of objects. System objects are devices or components such

as transformer, bus, branch line, connecting line, switch, fuse, earth, etc, topology relation includes extend（line）,connect（components）， different objects may have different kind of state, for example, bus device has ‘serve’, ‘hot reserve’, ‘cold reserve’, ‘repair’, while switch component has only two state, ‘opened’ and ‘closed’.

3.2. Knowledge Model Implementation

In system implementation, we use SHOP2 planner for OOS system construction. The following examples are some parts of knowledge base.

Example 1 description of system model

```
(transformer trans1)          //transformer object and type
(transformer trans2)
(bus  b220kv1)                //bus object and type
(bus  b220kv2)
(bus b220kv4)
(branch  line1)               //branch line object
(branch  line2)
(line l1-1)                   //line object and type
(line l1-2)
(ext l1-1 b220kv2 side2)      //system topology
(ext l1-1 s21-2 side1)
(ext l1-2 b220kv1 side2)
(ext l1-2 s21-1 side1)
…
```

Example 2 tasks and method model

```
//sub-system decomposition
(:method (db-bus-bypass-serve-to-cold-reserve ?bs)
 ( //recursive task decomposition
case1    (( stoped bus-protective-device)
            …)
((start-bus-protective-device )
             (db-bus-bypass-serve-to-cold-reserve ?bs))
case2   ((bypass ?bp1)(fuse ?fs)(include ?bp ?fs)
           …
(installed   ?fs))
((uninstall ?fs)
(db-bus-bypass-serve-to-cold-reserve ?bs))
 case3  (…)
((close ?s1 )
            (db-bus-bypass-serve-to-cold-reserve ?bs))
  …
)
)
//operating task decomposition
(:method (open ?sd)
    ()
    ((!open ?sd)
     (!check-opened ?sd))
)
(:operator (!open ?s)           //operator description
((switch ?s)(closed ?s))        //Precondition
((closed ?s))                   //delete list
((opened  ?s))                  //add list
)
```

Example 3 problem instance

```
initial-state:
(serve b220kv1)                 //component state
(serve b220kv2)
        (serve trans1)
```

```
(serve trans2)
(serve-on trans1 bs1)
(serve-on trans2 bs2)
(serve-on line1 bs1)
(serve-on line2 bs2)
...
goal:
((switchstate b220kv1, on-serve, on-cold-reserve))
```

Example 4 part of a produced operating order

```
!start       220kv-protective-device
!check       220kv-protective-device
!turn-off    CSQ-2
!turn-off    LFP-902A
!uninstall   fs20
!check-state fs20
...
```

3.3. Discussion

Contrasting with rule based expert system, this HTN planning based approach have some new features:

(1) Task oriented knowledge description mechanism can describe the hierarchical relation of scheduling task explicitly. During knowledge base construction, new task and decomposition method can be inserted into HTN at a proper location. This mechanism can reduce knowledge conflict during knowledge base construction.

(2) Operator oriented description can make operating action being described directly. When a plan is generated, the plan is also verified by state transformation. So the plan is acceptable logically.

4. Related Works

In OOS domain, more works have been down in development level but not research level in china. The major approach in development is production rule-based system.

Zhou M.[1] used a hierarchical manage mechanism to organize large production rule base. Device , system and components is classified according to their type, structure and functions. This approach is mainly a GUI approach and neither new knowledge description mechanism nor new problem solving approach is introduced. So it is hard to be research systematically.

Sylvié Thiébaux [7] proposed Power Supply Restoration (PSR) domain as a real world problem for AI planning. It is partly relevant to OOS domain. But most of current research is concentrated on STRIPS like planning,. Task hierarchy does not introduced as knowledge.

Our work is using HTN as hierarchical knowledge to describe relations between different level of tasks and domain models.

5. Conclusions

Appling HTN planning approach is a new direction in OOS domain. Identifying domain mode and task form in different levels is crucial in this approach. With the refinement of domain model, task can be also refine to operating action. Task decomposition in sub-system needs more domain knowledge and experience.

Current model is based on relatively simple operating actions description. More different cases and actions should be implemented to improve and complete knowledge base. Deep research should be done to sub-system task decomposition to extract more classical mode. A GUI for building such task decomposition strategies should also be explored in the future.

Acknowledgements

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The PDES Workbench

Roman VAN DER KROGT[1] and James LITTLE
Cork Constraint Computation Centre,
University College Cork, Cork, Ireland

Abstract. Central to the operation of a manufacturing plant is the planning and scheduling of the activities that take place. The quality of the plans and schedules produced has significant impact on the effectiveness and efficiency of a company. These schedules are restricted by the constraints imposed upon them by the design of the plant. However, while expert designers are able to roughly predict the outcome of a design in terms of its overall throughput, quantitative figures on future schedules are not usually produced. By implication, design constraints may be found to be expensive in scheduling terms during the operation of the plant and at a stage when improvements are hard or expensive to make.

This paper presents the PDES Workbench, a graphical system that is able to generate plans and schedules based on real-life manufacturing plant designs. This allows a manager or planner to assess the schedulability of a particular design at an early stage. When a schedule is found to be flawed in any aspect, it may not be apparent what to change in the design without degrading other aspects of the schedule. Therefore, the system is equipped with a case-based reasoning system that is able to proactively suggest ways of improving the design for improved scheduling results.

Keywords
Advanced planning and scheduling, process design optimisation

1. Introduction

Manufacturing processes are complex; often, involving a large number of resources and activities within a diverse set of restrictions. To achieve an efficient use of these resources, Advanced Planning and Scheduling (APS) techniques can be employed, such as discussed in e.g. [1]. The effectiveness of these techniques depends to a large extent on the process design. Indeed, we argue that the design of the process has a profound impact on the schedulability of the activities involved and the quality of the resulting schedule. Since the quality of the schedules has a direct influence of the production cost, it is important to take this into account during the design of processes. However, as suggested by Prasad [2], "process improvement is often perceived as an after-thought – a functional service to be called upon periodically for productivity improvement". One of the reasons for this is due to the complicated interactions between the different activities in the manufacturing process. The designer of such a process cannot exactly predict the scheduling behaviour of a design, as it may introduce several constraints that only become apparent during the actual scheduling process.

The case studies for our research are based on a large manufacturer of contact lenses. These lenses are produced in a two-step process, which consists initially of a

[1] Corresponding Author; E-Mail: roman@4c.ucc.ie

moulding process that produces moulds. The moulds are then used (and later destroyed) in the *casting* step, which creates the actual lenses. Due to stability considerations, moulds can only be used within a specific time window after their production. There are also different ways in which the mould stock can be managed, further adding complications to the schedule. Aspects such as this make it hard, even for an expert, to predict the schedule from a design.

This paper introduces the PDES workbench, a prototype tool that can assess the quality of schedules that result from a certain design. Constraint-based techniques are used to model and efficiently produce the schedules we are interested in, whereas techniques from A.I. and more specifically case-based reasoning are used to learn from previous designs in suggesting improvements. The prototype was built for the particular manufacturing company that we described, but with adaptability and extendibility in mind. As such, we believe that it is also applicable to other manufacturing domains.

This paper is organised as follows. First, we briefly describe the techniques that we have employed, constraint-based scheduling and case based reasoning, and the reasons for choosing these approaches. We proceed in Section 3 by describing the specific case to which we have applied to tool, and show how the design of the tool follows from that. Then, we evaluate the tool by showing the kind of scenarios it can deal with and finally, we draw conclusions in Section 5.

2. Relation to Existing Techniques: APS & CBR

The two techniques upon which the PDES workbench is built are constraint-based planning / scheduling to determine the schedulability of a design, and case-based reasoning to improve upon flawed aspects of a design. This section briefly introduces the two techniques.

2.1. Constraint-based Planning and Scheduling

Constraint programming is a problem solving methodology built around the identification of variables within a problem, a domain of values for each variable, and a set of constraints that specify which combinations of values are allowed. A solution is an assignment of values to variables such that all constraints are respected. With the addition of optimisation criteria, constraint programming is a rich mathematical infrastructure that can be used to model and solve a variety of economically interesting problems such as scheduling [3;4].

Constraint programming is a proven technology in scheduling optimisation for manufacturing enterprises. For example, the scheduling of production and delivery as well as the efficient use of raw materials are all problems for which CP-based solutions exist from such vendors as SAP, Oracle, and i2. Other reasons for choosing a constraint-based solution over other scheduling techniques are the facts that it is both rich and efficient. Its richness enables us to create models that capture all the details of a particular design, while its efficiency ensures that we can quickly produce acceptable solutions.

2.2. Case-based Reasoning

Case-based reasoning (CBR) is another problem solving strategy. It is based on reusing experience gained in previous problem solving episodes [5]. CBR starts from a previously generated solution and adapts this solution to match the current problem. This method of problem solving is akin to the way humans appear to solve certain problems [6].

In a CBR system, expertise is embodied in a library of previous *cases*. Each such case consists of a description of the problem along with its solution. If a new problem is to be solved, the following steps are taken:

1. *Case retrieval*. The new problem is compared with the cases in the library, and similar cases are retrieved.
2. *Case reuse*. If the problem does exactly match one of the cases just retrieved, we can reuse the solution that was recorded. If an identical problem was not found, the retrieved cases are used to suggest a solution to the new problem
3. *Solution revision*. The solution that was constructed in step (2) is tested to see if it is indeed a valid solution to the problem at hand. If it is not, the solution has to be revised.
4. *Case Retention*. The last phase involves deciding whether the current problem and its solution should be committed to memory as a case, or whether it is too similar to the existing cases.

One of the advantages of case-based reasoning is that it can be used in situations where knowledge acquisition is hard or impossible due to the fact that there are no known rules governing such a complex situation. This is the primary reason for us to employ this technique.

3. Design of the Tool

We have developed a research prototype tool in collaboration with a large manufacturer of contact lenses. As we indicated in the introduction, the complicated process used to manufacture the lenses is both an example and the motivation of our work: the subtle constraints imposed by the design on the possible schedules are hard to predict. However, even though we built the prototype with a particular application domain in mind, it was designed to be both adaptable and expandable as we detail below.

The architecture for our system can be seen in Figure 1. Our implementation allows different manufacturing process designs to be evaluated through a flexible user interface which interacts with a constraint-based optimiser and a case-based reasoning module for design improvements. The prototype is based on common desktop tools, which are readily accepted as standard in many industrial organisations. The graphical frontend to the workbench uses MS Visio to represent the product routes through the factory and the actual layout of machines on the factory floor, see Figure 2. The advantage of this setup is that the user can easily relate the information on screen to the actual circumstances. The tool allows exploring what-if scenarios by easily being able to add machines to the current design, remove them, or alter their characteristics (such as production rates). It also permits the alteration of a number of parameters of the process itself (such as the level of buffer stock between the two steps of the process or the stabilisation times), as well as changes to demand patterns.

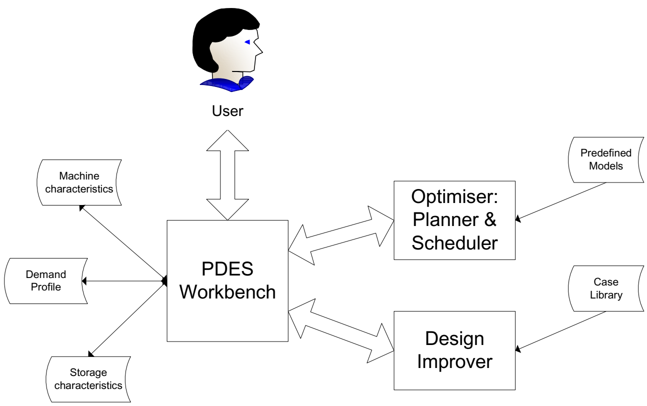

Figure 1. Overview of the architecture of the system.

Within the system, the process design is converted into a plan of necessary activities and then an optimisation data file. This is passed to the optimiser, where an appropriate pre-built model is selected (see [7]). The optimiser in this case is ILOG OPL Studio [8], a constraint-based problem solving technology that offers a variety of built-in solving techniques.

The models and their solution algorithms are selected such that they quickly produce an initial solution, and produce more refined solutions given more time. This way, the user may explore a number of scenarios quickly, while studying promising scenarios more thoroughly by allocating more time to the optimiser. Initial solutions are typically found within one to two minutes. The results that we present in the next section were achieved with 10 CPU minutes.

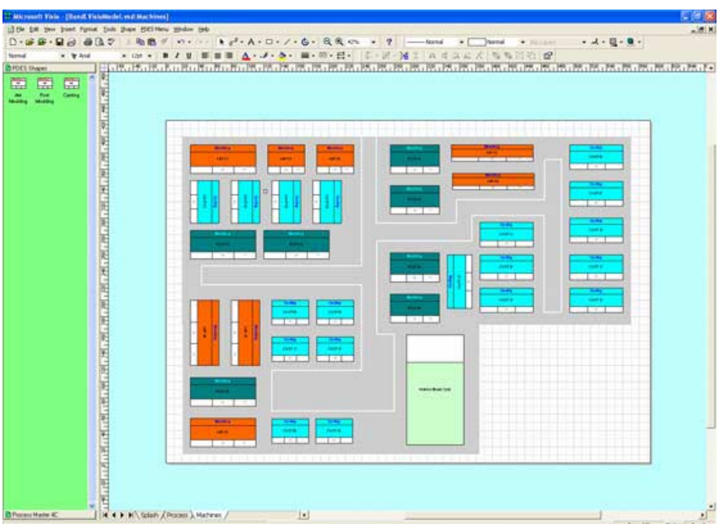

Figure 2. Graphical User Interface of the Workbench.

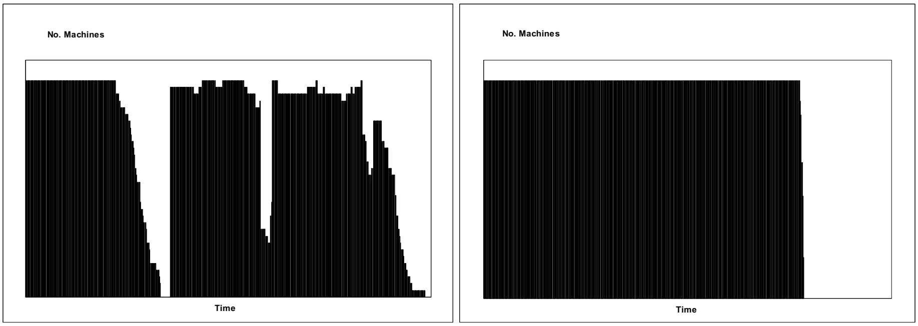

Figure 3. Examples of resource profiles.

Once the schedule is obtained, then the key performance indicators of manufacturing time, utilisation and lens production are calculated. These results are then presented to the user within MS Excel. This desktop tool has a sufficient level of functionality in statistical analysis and also in the representation of data as tables, charts and graphs. The next section contains a number of examples of the latter.

Should one or more performance indicators be unsatisfactory or even if the design is so flawed that no valid schedules can be produced for it, the user can ask the Design Improver subsystem to recommend changes to the current design. This part is implemented in Visual Basic using Excel files to store the case library. To obtain a recommendation, the user has to indicate which performance indicators are to be improved, and the relative importance of each of those indicators, in case a trade-off has to be made. The CBR system then compares the design and the demand pattern with previous designs and patterns, and selects those cases that resemble the current problem using a Euclidean distance measure. These cases are subsequently presented to the user, ranked according to the improvements that can be made to the chosen performance indicators. The user may then apply the recommended changes and evaluate the results again.

4. Evaluation

The PDES workbench has been validated by verifying a number of historical situations that the company experienced. In all cases, the predictions made by the planner / scheduler matched the experiences of the company and indeed suggested others which were not. The Improver subsystem was evaluated for user experience, as no historical data was available within the company for this type of system. The scenarios evaluated are presented below.

4.1. Historical Evaluation

The first scenario involved the level of buffer stock kept between the moulding and casting processes. The company currently holds more stock than necessary to ensure smooth casting operations. If casting were to fail, e.g. due to faulty moulds, then with insufficient stock the company would have to produce moulds again from the start. This would impact their schedule, by having to stop casting. In this scenario, we explored different levels of stock and showed the effect on the resulting schedules. One

of the aspects here is the operations of the casting machines. Figure 3 shows the resource profiles for the casting machines for two cases.[2] On the left, we have a minimal amount of stock. As one can see, the casting machines are not fully used throughout, as there regularly are intervals in which not enough moulds are available to keep all casting machines running. On the right-hand side, we have a situation in which enough stock is kept to keep the machines running. Not only does this lead to a much smoother operation of the casting machines, also the time to produce the required products decreases. By exploring different levels of stock, and weighing the savings gained by a smoother and quicker casting against the cost of higher stock levels for different scenarios the company was able to confirm their current stock levels were satisfactory. However they could design lower stock levels and still achieve an acceptable schedule in which all lenses were manufactured in time.

The second scenario revolved around the material of the moulds. The supplier announced a new type of plastic, with different stabilisation parameters (defining the time window within which a mould is to be used). To investigate the effect of this new material on the manufacturing process, we simply had to change the parameters defining the moulding material and examine the quality of the produced schedules. As we can see from Table 1, it turned out that, perhaps surprisingly, the new material with the "improved" characteristics had a dramatic effect on the schedulability: unless full stocks were kept, there were instances where the new material prevented feasible schedules to be produced.

Table 1. Schedulability for different materials

material	stock level	makespan	moulding util%	casting util%
original	minimal	7.11	96.3%	88.2%
	50%	5.51	90.5%	85.6%
	full	5.18	96.3%	99.3%
new	minimal	-	-	-
	50%	-	-	-
	full	5.68 days	96.3%	99.3%

The third scenario explored changes to the demand pattern. In this case, one can leave the design of the factory as it is and input different sets of orders to see how well the design can deal with these sets. Alternatively, one can use the tool to see what the best response is to a foreseen change in orders. As a particular example, we refer to Table 2. Here, we investigate (for a representative, but smaller set of weekly orders and a scaled-down factory) the effect of a 12.5% increase in volume. As we can see from the second row, the current design cannot cope with this increase, as it would take 7.1 days to produce the weekly demand. The third and fourth rows explore the result of buying additional machines. The company saw this part of the system as accurately reflecting the outcomes of historical decisions. From this grew the confidence that this type of architecture could help support future decision-making.

[2] In the interest of the company, the figures are provided without scales.

Table 2. Effects from an increase in volume of orders

order size	# mould. mach.	# cast. mach.	mould util%	cast util%	makespan
100%	2x4	12	94.2	95.4	6.5 days
112.5%	2x4	12	95.4	99.6	7.1 days
112.5%	2x5	13	95.7	97.2	6.0 days
112.5%	2x6	14	95.8	93.6	5.3 days

4.2. Improving Design Using the Case-based Reasoning Module

We created a case library consisting of 15 designs and their schedules from three different order sets of different sizes (corresponding to 50%, 100% and 200% of an order set of representative size). We then presented the system with a flawed design, and asked the system to recommend design changes that would correct the flaw.

As an example, consider a design in which the total capacity of the moulding machines is not enough to produce enough moulds. This design and some of its KPI are listed in the first row of Table 3 below. When asked to improve upon the makespan of this design, the system is able to retrieve a similar design with two additional moulding machines, one of each type. This design resembles the current design to a high level, and improves the makespan by 10%. Notice that an improvement of 11% can be made by a more radical change in design. This design is presented only as the 2nd suggestion however, since it deviates from the current design too much.

Table 3. Designs suggested by case-base (simplified representation).

	# mould. mach.	# cast. mach.	mould util%	cast util%	makespan
Input	2x7	32	90.7	89.5	7.4 days
1st suggestion	2x8	32	92.5	90.8	6.6 days
2nd suggestion	2x4 (double speed)	32	96.6	92.8	6.5 days

5. Conclusions and Future Work

In this paper, we presented a tool to assess designs of a manufacturing process for their scheduling consequences. This is a valuable aid particularly for designers of complex processes. Such processes may introduce hidden constraints that only become apparent during the actual planning and scheduling of the resources. These hidden constraints make it hard to predict the behaviour of a system beforehand. The PDES workbench allows a designer to explore what-if scenarios early on in the design process to take the schedulability aspect of designs into account.

The prototype system was evaluated within a large manufacturing company. The company have viewed the system positively in addressing the types of problems they are faced with on a regular basis. Presently they are able only to evaluate a few scenarios when operation conditions change. The planning department now have visibility of the scheduling process and are able to plan the factory operation with some knowledge of the scheduling consequences. The tool has been used to validate

historical decisions. In all explored cases, the results of the tool corresponded with the experiences in the factory. The case-based reasoning module, although not used in a real-world setting, was perceived as a useful addition.

The layout of their packaging plant is a current design problem for which the system is to be used to evaluate options. Here there are different performance of machines and dedicated machines to products. These types of constraints are already built into the prototype system.

One specific area that we are looking into is the automatic generation of optimisation models given a process diagram. This would greatly reduce the effort required to adapt the tool to a specific domain.

The design components of the manufacturing process such as route plans, resource layouts and demand profiles are common to other types of manufacturing. For this reason we intend to apply the same methodology to different manufacturing processes.

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Process chains of machining tools

Prof. Dr. Norbert FREI [1], Prof. Dr. Rainer WEIGEL [2], Dr. J. STJEPANDIC [3], Richard WIESTT [4]

Abstract. For a smooth and fast workflow of the incoming orders up to the delivery of a product the integrated information supply of production-means (in particular of tools) is very important. 2D and 3D data of the manufacturing tools required in the process are fundamental for companies with machining. Reliable production processes require NC simulation and collision checks based on accurate, true-to-scale 2D or 3D tool models. In this article we describe the situation, where tools for a specific machining process are ordered from the tool manufacturer and how these 3D models could be used in subsequent processes at the client side.

Keywords. Machining-Tools, data exchange, STEP, machining simulation, process chain, ISO 13399, parametric

Objectives

Concepts for design, generation and the efficient use of three dimensional tool models in the process chain of

1. Procurement
2. Tool Management,
3. NC Programming and NC Simulation
4. Tool Presetting

will be described. Currently, no single capable 3D tool model exists for all these processes , and thus must be recreated for each specific processes even within a single company. We present a adaptable representation of the tool data models prepared by the tool manufacturer, which can be used in all subsequent processes. Thus the cumbersome recreation of same models for different sub processes can be avoided. A small example from a company in the aero industry should show this problem. This company models tools, ordered from the tool manufacturer, in their own CAD system so that it can be used in the CAM package. To verify the NC programs they use a NC simulation package. Since the interfaces between the CAD system and the simulation system looses important information required for a meaningful simulation, the company uses the design tools within the NC simulation package to recreate the tools a

[1] University of Applied Sciences NTB Buchs / Switzerland, norbert.frei@ntb.ch
[2] University of Applied Sciences NTB Buchs / Switzerland, norbert.frei@ntb.ch
[3] University of Applied Sciences NTB Buchs / Switzerland, norbert.frei@ntb.ch
[4] University of Applied Sciences NTB Buchs / Switzerland, norbert.frei@ntb.ch

second time. These two steps wouldn't be required, if the 3D models from the tool manufacturer would satisfy the information requirements for all processes. We will now present the different steps of the process chain in more detail before we present a possible solution for the adaptable representation.

Procurement

The information for ordering special tools requires information about the surface, finish and cutting conditions of the tool in the process. The tool manufacturer will use this information and designs the new tool according to the customer specifications. The requirements for 3D tool models must be considered therefore with regard to the refined representation about the entire process chain. In order to make the CAD model useful, tooling attribute information described in ISO 13399 must be attached to the model. Furthermore the CAD model must be represented in such a way that it can be used in different CAD/CAM and simulation environments. Thus a standard based on a neutral STEP (ISO 10303) format and ISO 13399 will be required so that the transformation of the model to the customer specific environment can be performed within a tool data management system.

Tool management

Tool management systems organize and manage data of tools, jigs and fixtures over the whole lifecycle. Special tool management systems provide complete integration with CAD/CAM-NC software, presetters, shuttles, simulation software and ERP systems. It is essential that the CAD model obtained from the tool manufacturer contains enough information in order to create process-specific data. In the NC-module of Pro/E for example the radius must be declared at the turning tool with "nose radius" and not as corner radius as specified in ISO 13399. Therefore the attributes in the CAD models with the naming conventions from ISO 13399 must first of all contain these information and then be converted into the required target systems. One should keep in mind that the information about the nose radius is implicitly contained in a STEP (ISO 10303) boundary representation of the tool, however in order to have an automated process this information must be made explicit via attributes. When the information, where this radius is in the CAD model is lacking, this information cannot be created automatically at all. So a tool management system must provide these mapping to the customer specific environment. We should state here that the whole procedure is only necessary for tools, which are far away from the standard catalogue tools. For standard tools or tools that are close to the standard the tool management system for example includes 2D/3D generators for generation of the 3D data with all required information.

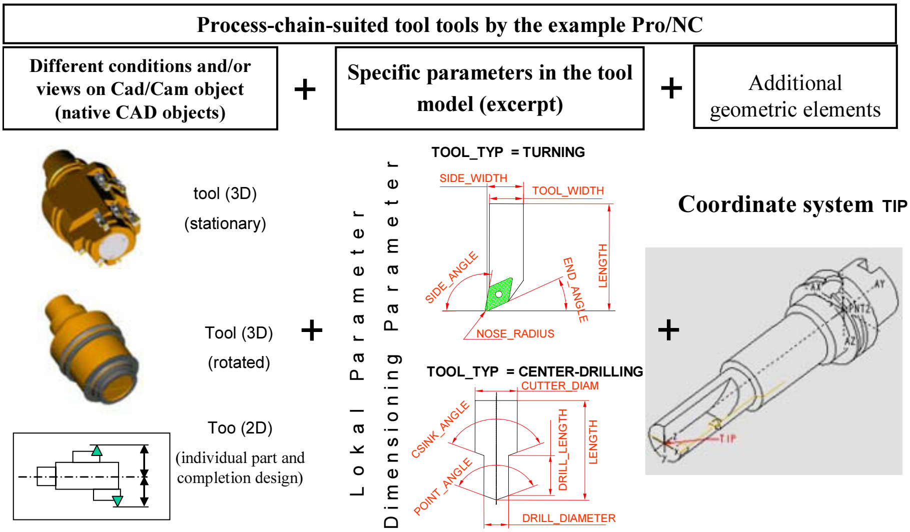

Figure 1: tool-requirements

NC Programming, NC Simulation and Tool presetting

Today many CAM systems still require only 2D-graphic information of the tools Our approach allows us to derive the 2D-graphic automatically from the three dimensional model. The main measurements of the tools and the definition of relevant measurement points with corresponding reference basis are fundamental for the tool preset. It is important that the drawings also comply with the BMG layer concept [1] [3] so that complete tools can be put together also with 2D-drawings.Figure 2 shows a milling tool in the BMG layer format. As an example, the delivery of tool data in BMG format is a prerequisite for DaimlerChrysler machining tool suppliers.

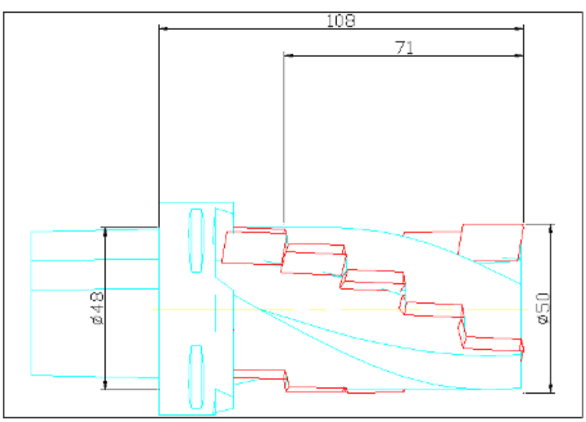

Figure 2: tool in BMG layer format ([1], [3])

Today's three-dimensional NC programming systems require, however, a native model (with specific parameters) and an assembly model. Complementary , application-specific parameters must be attached to the models, so that they are usable.

For the three dimensional simulation with collision detection complete tools are to be represented as a three dimensional model. For the simulation of the material removal it must be distinguished between cutting and not cutting tool geometry. The cutting edge is represented at rotationally symmetrical tools as rotated body. Additionally, with certain NC simulation systems the adjustable cutting tip must be put into the zero angle, so that the material removal occurs only with a two-dimensional face. Thus the adjustable cutting tip has to be rotated in the zero plane. So an angle error up to 3 degrees in the cutting angle results, which is not acceptable if the tool is used as forming shape.

In the following, we describe a solution for processing non-standard 3D tool data.

Problem solution

The integrated solution for the above-mentioned problem is shown conceptually in figure 3 (see also [2], [4]). It was implemented as a prototype and proven to be feasible. On the left hand side the tool manufacturer process of model preparation is shown. It consists of the following steps:

1. the design of the special tool in the manufacturer CAD/CAM environment (figure 4)
2. model simplification by removal of unnecessary detail geometry features
3. extend the CAD model by the additional attribute values described in ISO 13399
4. filter out company specific technological production knowledge, which must be protected. This is described in the next paragraph.
5. prepare the resulting native CAD model of the high end CAD system (UG, Pro/Engineer and Inventor in this project), so that the specific STEP format can be created. This preparation is currently done with the ClassCAD system plugged into the high-end systems (figure 5). This was necessary because current STEP processors available on the market do not have the necessary functionality. The extensions were made around the scheme AP214 and included parametric and constraints (ISO 10303-108/109: parameterization & constraints)

In the middle section of figure 3, the system must allow the particular process specific enhancements, a job that is usually done in the tool management system.

1. Conversion of the STEP-data to XML base classes.
2. Transformation with XML-transformation methods for the following process (for example NC-programming as described above).
3. Return transformation of the adjusted XML base classes to STEP.

ClassCAD has a modular structure with approximately 25 base classes (figure 5), which correspond roughly to the STEP entities. These contain CAD-basis features, parametric relationships, constraints and operators. In the prototype both the exchange of parametric three-dimensional parts and also assemblies with geometrical constraints were tested.
The specific enlargement and adaptation of the CAD models, like for example the changing of parameter names or the addition of NC-specific coordinate systems were solved with XML transformations.

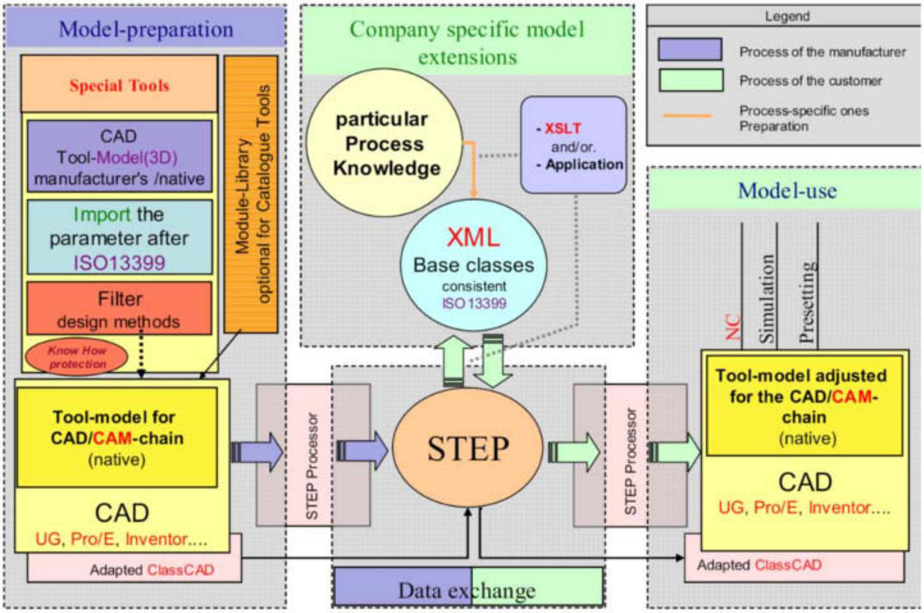

Figure 3: concept for the solution

On the right hand side one can see the STEP import into the target system (see figure 5) and how it can be used in the target system.

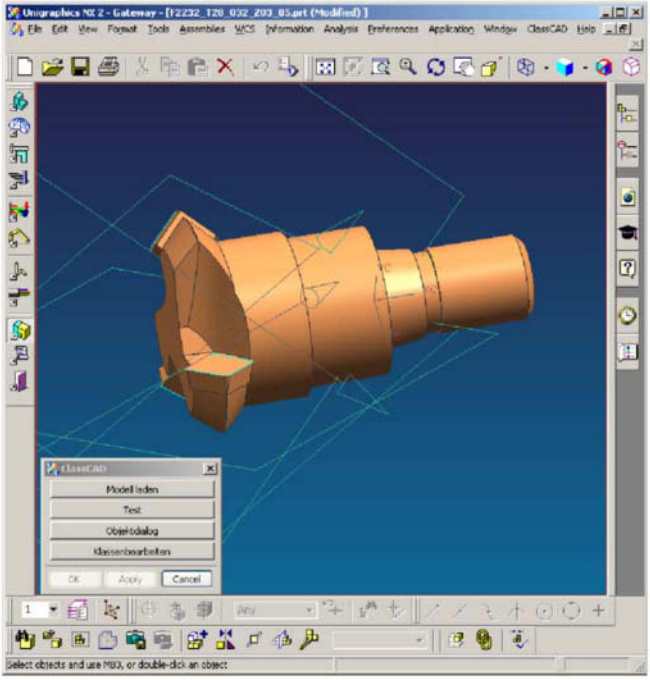

Figure 4: tool model in UG

Table 1: transformation tables (base classes, UG, Inventor, Pro/Engineer, STEP)

Base classes	UG classes	Inventor classes	Pro/E-classes	STEP Entity	Description
CC_Line startPt: CC_Point endPt: CC_Point	UG_Sketch Line	Inv_Sketch Line	Proe_Line	polyline	line in a sketch. startPt:start point endPt: end point
CC_Arc startPt:CC_Point endPt: CC_Point bulge: double	UG_Arc	Inv_Arc	Proe_Arc	b_spline_ curve	arc in a sketch. startPt:start point endPt: end point bulge: bulge = tan(a/4) with a = angle
CC_Circle center: CC_Point radius: double	UG_Circle	Inv_Circle	Proe_Circle	circle	circle in a sketch. center: center radius: radius
CC_Ellipse center: CC_Point radiusMin:double radiusMax:double	UG_Ellipse	Inv_Ellipse	Proe_Ellipse	ellipse	ellipse in a sketch. center: center radiusMin: smaller radius radiusMax: larger radius
CC_Point pos: double[3]	UG_Point	Inv_Point	Proe_Point	Cartesian point	point in a sketch. pos: point coordinates

Know how protection

The protection of company-specific data and knowledge of the tool manufacturers is a overall problem in the exchange processes and one of the most important reasons for the delayed implementation of the form feature and parametric functionality within the commercial STEP translators. Especially the suppliers fear that the high level data exchange could cause the unintended sharing and lost of their company know how. The exchange of the CAD models containing only the boundary representation is also used as a kind of the know how protection.

In our case the model simplification and the know how protection can but must not be combined. The approach for the know how protection by model simplification is described in [6]. Therefore the special knowledge based engineering modules can be used to acquire, capture and remove the design knowledge within/from CAD model. So a “model for exchange” containing for example only the necessary form features but no parametric relation can be derived from the original model. The other possibility belongs the interface filter like entity, layer or colour filter in the commercial translators. For example: if the translation mode “no parametric” is switched on, the translator should be able to translate the whole model content (form features, constraints, explicit geometry, attributes etc) but no parametric information. Because of complex relationships like cross over parametric in an assembly the idea of intelligent filters was invented and used principally in this work. But as the objective did not lie in this area only basic solutions were developed here.

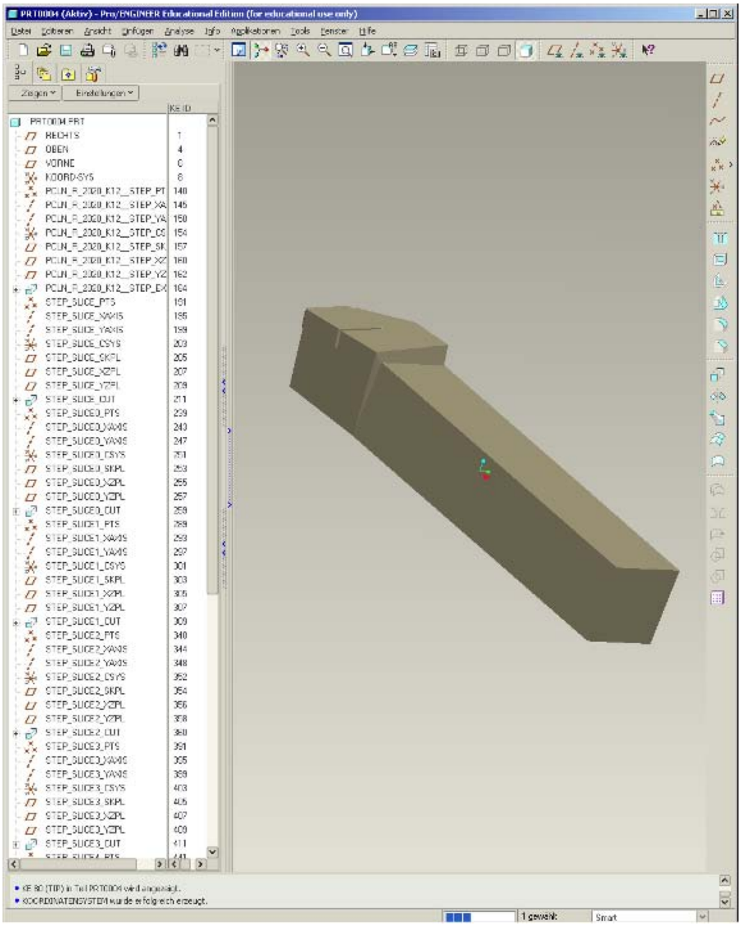

Figure 5: converted tool in Pro/Engineer

Summary

With the realized prototype it could be shown, that it is feasible to exchange data with the above concept (see figure 3) on the basis of standards (STEP and ISO 13399). However it was necessary to enhance STEP-processors by parametric and constraints (ISO 10303-108/109) and to add to the CAD-models of the tool manufacturer attributes according to the norm of ISO13399.
With these two extensions and intelligent filters, that protected the company knowledge of tool manufacturers, it should be possible in future to exchange tool data in different areas without the need of additional effort of tool manufacturers.
The works on this area will be continued in the project group " 3D parametric data exchange via STEP" within ProSTEP iViP e.V. The next use cases are the exchange of the standard parts and fix & jigs.

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Parallel *hp*-Finite Element Simulations of 3D Resistivity Logging Instruments

Maciej Paszyński [a,1], David Pardo [b] and Leszek Demkowicz [b] Carlos Torres-Verdin [c]
[a] *Department of Computer Methods in Metallurgy, AGH University of Science and Technology*
[b] *Institute for Computational Engineering and Sciences, University of Texas at Austin*
[c] *Department of Petroleum and Geosystems Engineering, University of Texas at Austin*

Abstract. The electromagnetic (EM) measurements obtained by using one transmitter and one receiver antenna in a borehole environment are simulated. The measurements are used to assess electrical properties of rock formations. First, logging instruments as well as rock formation properties are assumed to exhibit axial symmetry around the axis of a vertical borehole. The optimal mesh for axially symmetric problem is obtained by a 2D self-adaptive goal-oriented hp-Finite Element Method (FEM) that delivers exponential convergence rates in terms of the quantity of interest against the CPU time. The 3D mesh is obtained by full revolution of the generated 2D mesh. The computations are then performed for angles of formation layers deviated by 30, 45 and 60 degrees. The concurrent engineering infrastructure that solves the problem automatically in parallel is presented. The 3D code has been verified by comparison of numerical results with the known exact solution of the problem of antenna radiating into a homogenous space, and by comparison of results of 2D and 3D code for the problem with axially symmetric layers in formation.

Keywords. Automatic *hp*-adaptivity, Finite Element Method, Parallel algorithms, Computational electromagnetics

1. Introduction

The motivation of this work is to simulate 3D Logging-While-Drilling (LWD) measurements in deviated wells. The 3D LWD electromagnetic (EM) measurements are obtained by using one transmitter and one receiver antenna in a borehole environment, as it is presented in Figure 1. The receiver and transmitter antenna are shifted along the borehole, and the very accurate value of the solution (potential of the electromagnetic wave) must be obtained at the receiver antenna for each logging position.

The problem with formation layers perpendicular to the borehole was successfully simulated by 2D goal-oriented *hp* adaptive finite element code, using axially symmetric formulation in the cylindrical system of coordinates [3], [4]. However, the fully 3D problem with deviated wells requires an expensive sequence of 3D computations for many position of transmitter and receiver antenna. To reduce the computational cost of

[1]Correspondence to: AGH University of Science and Technology, Al. Mickiewicza 30, 30-059 Kraków. Tel.: +48 12 617 3812; Fax: +48 12 617 2921; E-mail: paszynsk@agh.edu.pl

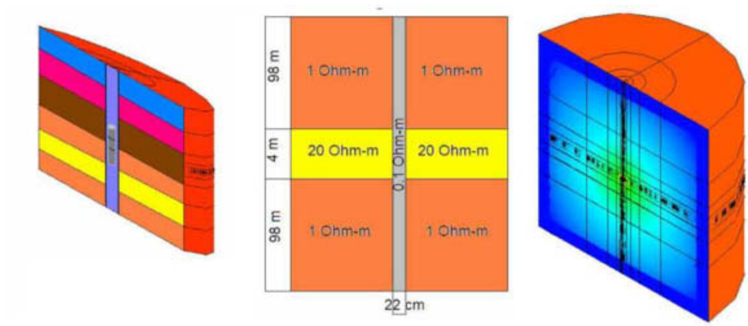

Figure 1. Left-hand-side picture: Simulation of 3D problem in deviated wells, possibly with steel casing, and with several layers in the formation. **Middle picture:** The solution to the problem of antenna radiating into a homogenous space. **Right-hand-side picture:** Layers with various resistivities in the formation.

the problem, the concurrent engineering (CE) tools must be applied. The paper presents application of the parallel distributed infrastructure, with domain decomposition (DD) based 3D *hp* finite element solver [13], created by the group of Demkowicz [13], [12], [5], [6], [9]. The use of *hp* finite elements allows to mix elements with various size and various polynomial orders of approximation over the same mesh. The design details of the parallel distributed infrastructure are discussed.

2. Maxwell's equations

2.1. Time-harmonic Maxwell's equations

Assuming a time-harmonic dependence of the form $e^{j\omega t}$, with ω denoting the angular frequency, Maxwell's equations can be written as

$$\begin{cases} \nabla \times \mathbf{H} &= (\sigma + j\omega\epsilon)\mathbf{E} + \mathbf{J} & \text{Ampere's Law,} \\ \nabla \times \mathbf{E} &= -j\omega\mu\,\mathbf{H} & \text{Faraday's Law,} \\ \nabla \cdot (\epsilon\mathbf{E}) &= \rho & \text{Gauss' Law of Electricity, and} \\ \nabla \cdot (\mu\mathbf{H}) &= 0 & \text{Gauss' Law of Magnetism.} \end{cases} \tag{1}$$

Here $\mathbf{H}$ and $\mathbf{E}$ denote the magnetic and electric field, respectively, $\mathbf{J}$ is a prescribed, impressed current source, ϵ, μ, and σ stand for dielectric permittivity, magnetic permeability, and electrical conductivity of the medium, respectively, and ρ denotes the electric charge distribution.

Maxwell's equations are not independent. Taking the curl of Faraday's Law yields the Gauss' Law of magnetism. By taking the curl of Ampere's Law, and by utilizing Gauss' Electric Law we arrive at the so called continuity equation,

$$\nabla \cdot (\sigma\mathbf{E}) + j\omega\rho + \nabla \cdot \mathbf{J} = 0\,. \tag{2}$$

2.2. *Steady State Maxwell's equations*

At Direct Current (DC, *i.e.*, $\omega = 0$), the time-harmonic Maxwell's equations reduce to,

$$\begin{cases} \nabla \times \mathbf{H} = \sigma \mathbf{E} + \mathbf{J} & \text{Ampere's Law,} \\ \nabla \times \mathbf{E} = 0 & \text{Faraday's Law,} \\ \nabla \cdot (\epsilon \mathbf{E}) = \rho & \text{Gauss' Law of Electricity, and} \\ \nabla \cdot (\mu \mathbf{H}) = 0 & \text{Gauss' Law of Magnetism.} \end{cases} \tag{3}$$

Similarly, the continuity equation reduces to,

$$\nabla \cdot (\sigma \mathbf{E}) + \nabla \cdot \mathbf{J} = 0 \,. \tag{4}$$

For simplicity, we shall assume that the solution domain is simply connected. Faraday's law implies that there exists a scalar potential u such that,

$$\mathbf{E} = -\nabla u \,. \tag{5}$$

The continuity law (here understood in the distributional sense) implies that, in the subdomain occupied by conductive media, the potential must satisfy the so called *conductive media equation*, *i.e.*,

$$\nabla \cdot (\sigma \nabla u) = -\nabla \cdot \mathbf{J} \,, \tag{6}$$

accompanied by homogeneous[2] Neumann boundary condition on the conductive/non-conductive material interface,

$$\sigma \frac{\partial u}{\partial n} = 0 \,. \tag{7}$$

The paper focuses on the computation of an electrode in a dipped borehole at zero frequency (DC), by using the equation (6).

3. Components of the concurrent engineering infrastructure

The CE engineering infrastructure designed to perform a sequence of computations for many logging positions is presented in Figures 2 and 3. The *Main* component is responsible for executing a sequence of computations for various logging positions and for various angles of formation layers. The *Geometry Modeling Package (GMP)* component is called to generate geometry of the borehole and layers of the formation. The FE mesh is generated for each logging position, based on geometry data stored in *GMP* component, and stored in *FE mesh* component. The *Parallel multifrontal solver* is executed to solve the conductive media equation (6). The solver must generate local matrices for all finite elements from the computational mesh, by calling the *Integration* component with geometry of a finite element obtained from the *FE mesh* component.

[2]Unless the normal component of the impressed current is discontinuous across the material interface. In such a case, $\sigma \frac{\partial u}{\partial n} = [\mathbf{n} \cdot \mathbf{J}]$ where $[\mathbf{n} \cdot \mathbf{J}]$ denotes the jump of the normal component of $\mathbf{J}$

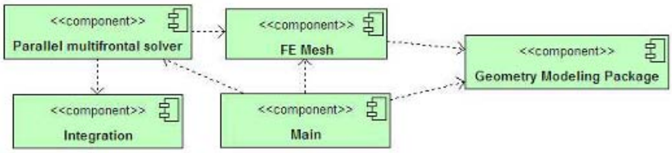

Figure 2. Components of the CE infrastructure.

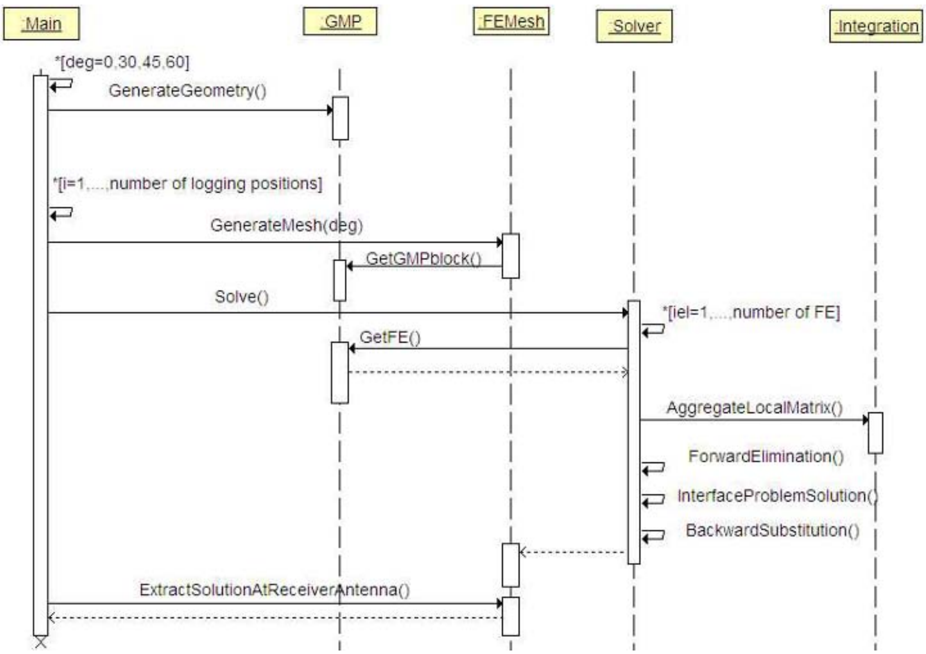

Figure 3. Execution of the infrastructure.

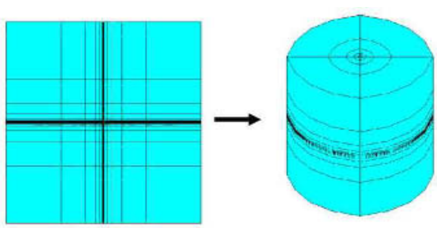

Figure 4. The 3D mesh obtained by a full revolution of the 2D mesh.

4. Numerical results

The computations presented in the chapter use finite element mesh presented in Figure 4, designed by hand, based on the optimal 2D mesh provided by 2D goal-oriented *hp* adaptive code [3], [4], [14]. There are one transmitter and one receiver antenna in the

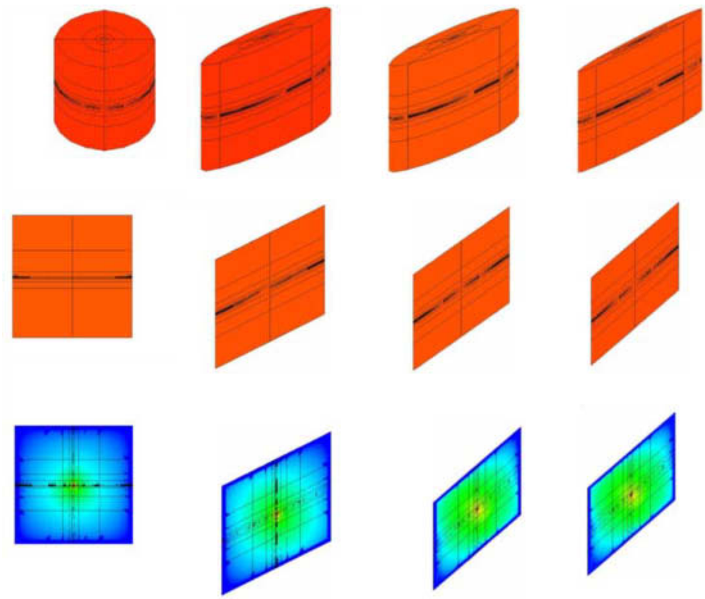

Figure 5. Top picture: 3D mesh bent by 0, 30, 45 and 60 degrees. **Middle picture:** Front view on the cross-section of the 3D mesh . **Bottom picture:** Solution to the problem drawn on the cross-section. The finite element mesh used provides accurate solution at the receiver antenna.

computational domain. The 2D mesh obtained from the goal-oriented code provides very accurate solution at the receiver antenna [3], [4], [14]. The 2D starting mesh is obtained by setting order of approximation $p = 2$ globally, and varying elements size based on the results of the optimal mesh provided by the goal-oriented code. The 3D mesh is obtained by full revolution of the 2D mesh, see Figure 4.

The 3D results have been verified by computing the problem of antenna radiating into a homogenous space with known analytical solution $\frac{1}{4\pi R\sigma}$, presented in Figure 1. The resulting value at the receiver antenna, coincides with the exact solution and with results of the 2D goal oriented code [3], [4], [14]. The computational domain for the ressistivity measurement problems includes loop shape transmitter and receiver antenna, located inside a borehole, with several layers in the formation, presented in Figure 1. There are various resistivity constants assigned to various formation layers. The resistivity of the target layer is assumed to be equal 20 $Ohm - m$. A sequence of computations for various angles of deviated wells, for 0, 30, 45 and 60 degrees, have been performed, as it is presented in Figure 5. The 3D finite element mesh has been bent for various angles of formation layers.

The computations for each angle have been performed in a sequence of locations of receiver and transmitter antenna. In other words, the entire tool has been shifted along the axis of the borehole. The computations for 60 positions of receiver and transmitter antenna have been made. The solution values have been extracted at the receiver antenna. The results of the 3D code have been compared with results of the goal-oriented 2D code, for the case of axially symmetric layers. The 2D code uses the formulation in the cylindrical system of coordinates [4]. There is a perfect agreement between results of

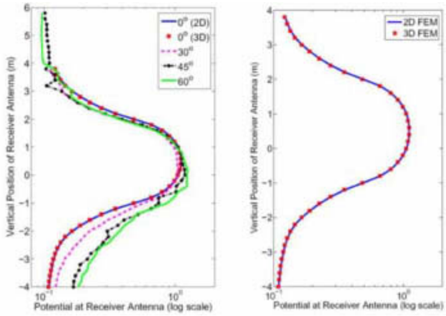

Figure 6. Left-hand-side picture: Potential at the receiver antenna for several angels of formation layers. **Right-hand-side picture:** Potential at the receiver antenna for fully axially symmetric case: comparison between 2D and 3D codes.

the 2D and 3D codes, as it is presented on the right-hand-side picture in Figure 6. The picture presents values at the receiver antenna for different logging positions.

Then, the sequence of computations have been repeated for deviated wells, with formation layers bent by 30, 45 and finally 60 degrees. The obtained results are drawn on the left-hand-side picture in Figure 6. The picture presents values at the receiver antenna for different positions of the antenna, for different formation layer angles. Not only finite elements modeling the formation layers have been bent, but also finite elements modeling the borehole and the transmitter and receiver antenna. This implies some disturbances in numerical results, especially for large angles.

5. Execution of the concurrent engineering infrastructure

The DD based 3D parallel *hp* finite element solver has been used to compute all results presented above. The parallelization is based on the DD paradigm. The *GMP* component presented in Fig. 2 is stored globally, the entire geometry data are stored as list of GMP blocks, such as curves, circles, ellipses, planes, and cylinders [17] on each processor. However, each processor generates a separate piece of the computational mesh, stored in *FE mesh* component, in distributed manner, as it is presented in Figure 7. An interface mesh nodes are enumerated globally in the *FE mesh* component. The forward elimination stage of the *Parallel multifrontal solver* is executed fully in parallel over each subdomain, and it is stopped *before* processing interface nodes. The global interface problem matrix is obtained now by simply sending all current local frontal matrices to separate processor, where they are summed up and the interface problem is solved. The solution is broadcast into all processors and the backward substitution step is run fully in parallel. Thus, the *Parallel multifrontal solver* utilizes distributed storage of data. The 3D solver is an extension of the 2D solver [12], based on [7], [16] solvers. There are two sequential parts of the code: the generation of the geometry, and the interface problem solution.

6. Performance measurements

The execution times for 1, 4 and 8 processors, for particular parts of the code, have been compared. The parallel solver uses one master process for the interface problem

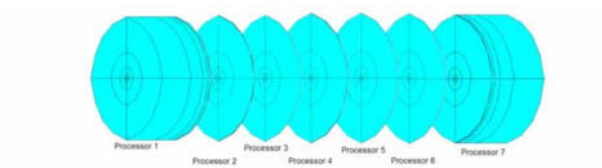

Figure 7. Computational domain decomposed into 8 pieces.

Number of processors:	1	3 + 1 master	7 + 1 master
Initialization	12s	12s	12s
Mesh generation	90s	31s	13s
Solver	39s	14s	6s
Total	141s	57s	31s

Table 1. Execution time for particular steps of the algorithm. simulation.

solutions. The computations involves the following steps

1. Initialization of the code, including generation of the geometry of the problem described in the input file [17], which is a sequential part of the algorithm.
2. Generation of the finite element mesh.
3. Solution of the problem.

For each logging position, steps (2) and (3) must be repeated. The geometry of the domain remains the same, only positions of transmitter and receiver antenna are changed, and the finite element mesh must be adjusted to provide accurate solution at the new position of the receiver antenna.

The measurements of efficiency of the parallel code have been performed. The total computation time for different number of processors has been measured, is it is presented in Table 1. The first part of the code, the generation of geometry, is purely serial, but this part must be executed only at the beginning of the simulation, and for each logging position only the mesh generation and solver are executed. Both parts scales very well, up to 90 % or relative efficiency [8].

7. Conclusions and Future Work

- CE infrastructure which automatically solves 3D ressistivity measurement problems in a sequence of logging positions in an efficient way has been developed.
- The parallel codes supports automatic *hp* adaptivity driven by energy norm. The code will be extended to support 3D goal-oriented *hp* adaptivity.
- The current parallel solver will be replaced by a new one, interfacing with MUltifrontal Massively Parallel Solver [10], which is 20 times faster then the current solver.
- The future work will also include goal-oriented *hp* adaptive computations of 3D problems in deviated wells, possibly with mandrel or casing, and with several layers in the formation. An anisotropy and invasion effects will be also studied.

Acknowledgements

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Knowledge Driven Optimization and Finite Element Analysis of Aircraft Structures

R. Curran [a,1], G. Gomis [a], A. Murphy [a], S. Castagne [a], P. Morenton [b], A. Rothwell [c]
[a] *Centre of Excellence for Integrated Aircraft Technologies, Queens University Belfast*
[b] *Laboratoire Génie Industriel, Ecole Centrale Paris, France*
[c] *Faculty of Aerospace, Delft University of Technology, Holland*

Abstract: The paper presents a knowledge driven methodology for the global integration of aircraft structural design based on structural analysis and manufacturing cost optimization relative to weight. The initial design of a fuselage structure is generated from a numerical solution considering the weight and manufacturing cost of the structure relative to Direct Operating Cost. That baseline configuration is then used as the geometrical definition that is analyzed at a more detailed level using the Finite Element Analysis (FEA) method. Fuselage panels are made of a skin-stringer assembly that locally buckles under normal flight loads. The finite element method has the potential to give a representation of the buckled shape as well as a value for the local critical buckling load of any mode investigated. The paper investigates the potential for adopting a suit of integration tools in the Dassault V5 platform in order to implement an iterative design, structural analysis and optimization process for fuselage panels. It is convenient to use the platform in order to obtain structural data that would then be reused in the optimization workbench built within the platform. Results from the fuselage finite element model are compared to both experimental data and theoretical predictions before being linked to the optimization tool. The fuselage panel is then optimized for minimum weight while still resisting an applied compressive load without buckling. The optimization process parameters are analyzed using statistical methods. It is shown that a fully integrated way of designing and optimizing fuselage panels is achievable. The paper therefore presents a methodology to implement and run an integrated design optimization of a structure loaded in compression. Consequently, the tool facilitates a concurrent engineering approach to the product development phase, both compressing lead time and improving the sharing of relevant multidisciplinary information, which traditionally tends to be carried out in a more serial manner.

Keywords: Finite Element Analysis (FEA), Fuselage Panel, Optimization, Digital Manufacturing Platform.

1. Introduction

The paper considers the use of the Dassault V5 Platform as a truly collaborative tool for aircraft life cycle optimization and presents research into the potential optimization of a fuselage panel under compression modelled with a Finite Element Analysis (FEA) (FEA).

[1] Corresponding Author, School of Mechanical and Aerospace Engineering, Ashby Building, Queens University Belfast, Stranmillis Road, Belfast, BT9 5AH. Tel: +44 (0)28 90974190, E-mail: r.curran@qub.ac.uk

Numbers of research groups are currently looking at Integrated Approach to Design and Digital Manufacturing [1,2,3]. This is not surprising since major aeronautical players are now using digital manufacturing tools. Digital manufacturing is an emerging software technology that has become a key component of Product Lifecycle Management (PLM). Moreover FEA methods are now widely studied [4,5] because they provide an effective way of investigating complex structural behaviors.

The profile used in this study is an abstraction of a fuselage panel, whose frame pitch is fixed as seen in Figure 1. This profile relates to the under body of the fuselage, supporting compression load only. In order to manufacture such a piece of structure a method is required to assess the structural behavior and the design at an early conceptual stage. However, the methodology presented in the paper also considers the impact of manufacturing cost and weight on the Direct Operating Cost (DOC) of the aircraft [6-11]. This is achieved through the integration of cost modelling at the concept design phase in order to provide an improved baseline design configuration to be considered in detail through with Finite Element Analysis (FEA). This type of integrated design method for aero structures would result in an automated cost optimization tool [11] such as that presented in the paper.

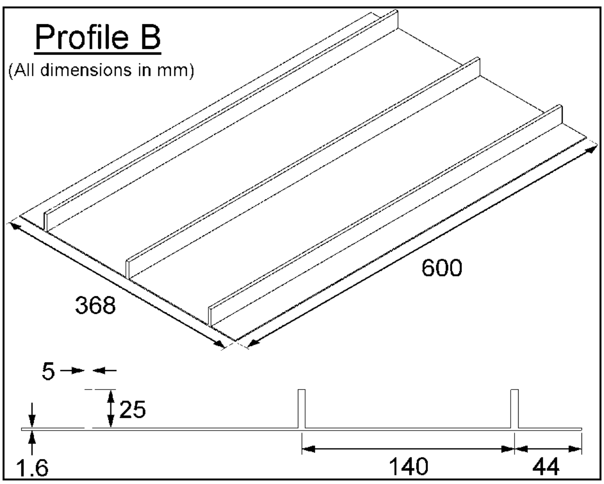


Figure 1. Experimental Panel Geometry

2. Problem Domain: Airframe Structural Analysis

This section sets out the problem domain by introducing Finite Element Analysis (FAE), the theoretical numerical basis and some experimental results.

2.1 Finite Element Analysis

In order to assess the finite element software – ElFini Solver – built into the Dassault V5 Platform we use a panel profile supporting in-plane compressive load. Several other studies have already investigated panels under compressive load but using other

commercial packages such as ABAQUS [4,5] that can perform post buckling studies. In this study only the local buckling is taken into account.

The final goal being to end up with a fully integrated solution, the requirements for the finite element solver are not the same as for an accurate simulation of panel post-buckling for example. The FEA computing time is an important factor since it will play a crucial role in the optimization process, therefore 2D meshes are used for the simulations since 3D solid elements are time consuming and not appropriate from an integration point of view. Moreover, the solution should not require any engineering knowledge to choose one mode among several possible or a buckling load instead of another.

Fuselage stiffened panels are built to allow the skin in between stiffeners to buckle below the ultimate failure load, in order to offer weight savings over non-buckling designs [12]. However in this study the panel is not allowed to buckle below the ultimate critical load, and is optimized for such a hypothesis. The results given by the solver are compared with theoretical and experimental data performed on a piece of panel including three stiffeners as shown on Figure 1.

The material properties of the panel tested are taken from specimens under compression loads. The alloy characteristics are not the same throughout the material because of difference in temperature during the panel manufacturing process.

We use a different modulus for the stringers and the skin, and weight these modulus to find a global average modulus for the whole plate.

The characteristics of the experimental material for Poisson Ratio and Young's Modulus respectively where: $\nu = 0.33$, and for $E_{skin} = 7.265 \times 10^4\, MPa$ and $E_{stringers} = 7.155 \times 10^4\, MPa$ the resulting value of:

$$E = \frac{E_{skin} V_{skin} + E_{stringer} V_{stringer}}{V_{total}} = 7.222 \times 10^4\, MPa$$

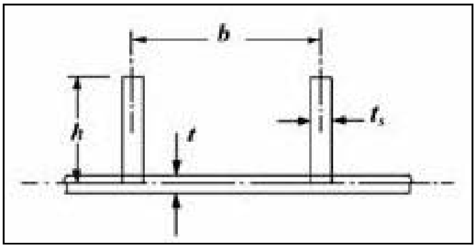


Figure 2. Theoretical parameters

2.2 Theoretical Basis

In order to compute the theoretical critical load at which the panel locally buckles we use ESDU 70003 data [13].

The assumptions made in this analysis are that the panel is simply supported on the loaded edges, with compression load uniformly applied.

The geometry of the panel is given on Figure 1, and the following data are therefore computed:

$\frac{b}{t} = 87.5$ (>5) and $\frac{h}{t_s} = 5.16$ (>5) so the data from ESDU 70003 are applicable (see Figure 2).

We compute the following ratios in order to get the elastic buckling stress factor:

$$\frac{ts}{t} = 3.125$$

$$\frac{h}{b} = 0.184$$

$$\Rightarrow K = 6.0$$

The average elastic compressive stress at which local buckling first occurs is given by

$$(f_b)_e = KE\left(\frac{t}{b}\right)^2$$

$$\therefore (f_b)_e = 56.6MPa$$

As we are well before critical yield in this experiment, no plasticity reduction factor has to be taken into account and we can therefore compute the critical load directly. We obtain the following value for the critical buckling load: .

$$(F_b)_e = 54.55kN$$

This value is different from the experimental one mainly because of the boundary conditions applied on the loaded edges of the experimental panel. Indeed the Cerrobend® on each side of the panel prevent it from rotating along the loaded edge axis, which affects the critical buckling load value. Moreover the material imperfections are not modelled in the theoretical value but would influence the experimental critical buckling load.

2.3 Experimental Results

The specimens were integrally machined by Alcan Aerospace and tested at Queen's University Belfast in a 250 kN capacity hydraulic, load-controlled compression-testing machine. A 42 mm thick Cerrobend® (low melting point alloy) base was cast on to the specimens, producing fully clamped boundary conditions at each end. Keying holes were drilled through the ends of the specimens prior to casting to hold the Cerrobend® in position and to help to prevent specimen-Cerrobend® separation. The ends were subsequently machined flat and perpendicular to the skin to ensure that uniform axial loads were applied. Strain gauges were located to assist in the determination of local buckling and post-buckling collapse behaviour. Two calibrated displacement transducers, one either side of the specimen, were used to measure specimen end-shortening. The specimen was loaded monotonically at a rate of 10 kN/min (approximately) until failure occurred, deflection and strain data were recorded automatically at 4-second intervals. Additionally, a non-contact Digital Image Correlation system was used to measure specimen plate out-of-plane deformation

during the test. Finally, two other profiles were tested to allow assessment of experimental repeatability [14].

Two main results can be deduced from the experimental work: the critical load at which local buckling first occurs and the deformed shape of the panel at buckling.

The critical buckling load found in the experiment is:

$$(F_b)_{exp} = 69.3kN$$

The deformed shape is obtained using Digital Image Correlation as shown on Figure 3. This type of pattern – 5 half waves along the skin element edge – is expected to be found while post processing the finite element buckling case within the Dassault V5 Platform.

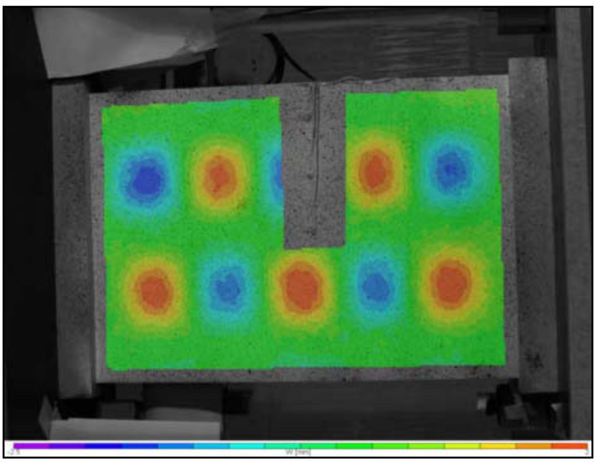


Figure 3. Profile B Experimental Deformation under 100kN Load

3. Concurrent Integration Methodology

This section sets out the methodology in two parts. The first part details the automated method for generating the geometry based on the weight-cost optimization process presented. The second part details the method used in the application of the Finite Element Analysis (FEA).

3.1 Geometry Definition

The methodology sets out the process steps that were developed for the generation of a fuselage panel design that was first optimized for Direct Operating Cost at a configuration level and then investigated for manufacturability at a more detailed level, including assembly, planning and the provision of all relevant data necessary for subsequent stages in the production.

1) The first step taken was to use a spreadsheet to generate the geometric definition of the panel. The spreadsheet analysis tool [11] is driven by a range of structural failure

limitations and design constraints which can be traditionally used to compute an optimized structural design, where the objective function is to minimize the weight of the structure, being a key driver in aerospace design. This is facilitated by inputting the loading conditions, some global design parameters (such as the panel length, panel width, and frame spacing); and stipulating constraints such as the material failure limit, minimal stiffener (stringer) spacing and minimal skin thicknesses. The fuselage panel is modelled as described in Figure 2 where 'T' shaped stringers are evident, which typically stiffen the skin along their length in order to prevent buckling. As well as calculating the skin local buckling criteria, stringer, flexural and inter-rivet buckling are considered for panels loaded in compression and shear. However, the spreadsheet has been modified to include the manufacturing cost associated with materials, fabrication and assembly of the panels. However, rather than only optimizing relative to some trade-off between minimum manufacturing cost and minimum weight, these have been combined into an expression for Direct Operating Cost, according to the following equation:

$$doc = fbc + \eta mfc$$

where *doc* is Direct Operating Cost ($ / m^2), *fbc* is fuel burn cost ($ / kg over the aircraft life), *mfc* is manufacturing cost ($ / m^2 of panel), and η is a scaling factor to account for the full impact of *mfc* on *doc*. Therefore, the optimization procedure already accounts for manufacturing cost relative to structural and operational requirements at this global level in generating a baseline, with the spreadsheet outputting the design variables illustrated in Figure 2. The optimization process is facilitated within the spreadsheet with the MS Excel Solver Add-on which provides a range of non-linear and genetic solvers; for example, from a standard gradient based method of steepest descent to genetic algorithms and simulated annealing. The optimization process can be carried out using for a range of these techniques and typically is run from at least three different seed positions in order to verify the global nature of the solution, rather than potentially accepting what is a local optimum.

Figure 4 illustrates that the spreadsheet operations are in the background and that a V5 Visual Basic (VB) interface is used for the input of data. The interface passes the pre-defined global parameters to the Catia module and the spreadsheet while the remaining variable magnitudes to be determined are optimized automatically in the spreadsheet and then passed to the Catia module, described in the next section.

2) The second step taken is the creation of the solid model that has been defined geometrically by Stage 1, as illustrated in Figure 4. The design of the fuselage panel can be generated automatically in CATIA as the spreadsheet analysis has been coupled through the design parameters and variables defined from the results [11]. Essentially, the design variables represented in Figure 2 are directly linked to the CATIA 3D-representation through a Knowledgeware© toolbar facility with the V5 Platform; allowing the geometric solid modelling to be parametrically driven directly by the spreadsheet. Consequently, the final product object in CATIA is updated whenever any change occurs among one of the five parameters outputted by the optimization procedure that influence the cost of the final product, i.e. b, t, t_s, h and r_p. Therefore, any analysis (in the background) and manipulation of the variables defined by the spreadsheet will be reflected in the V5 tool, without manually copying or manually the results.

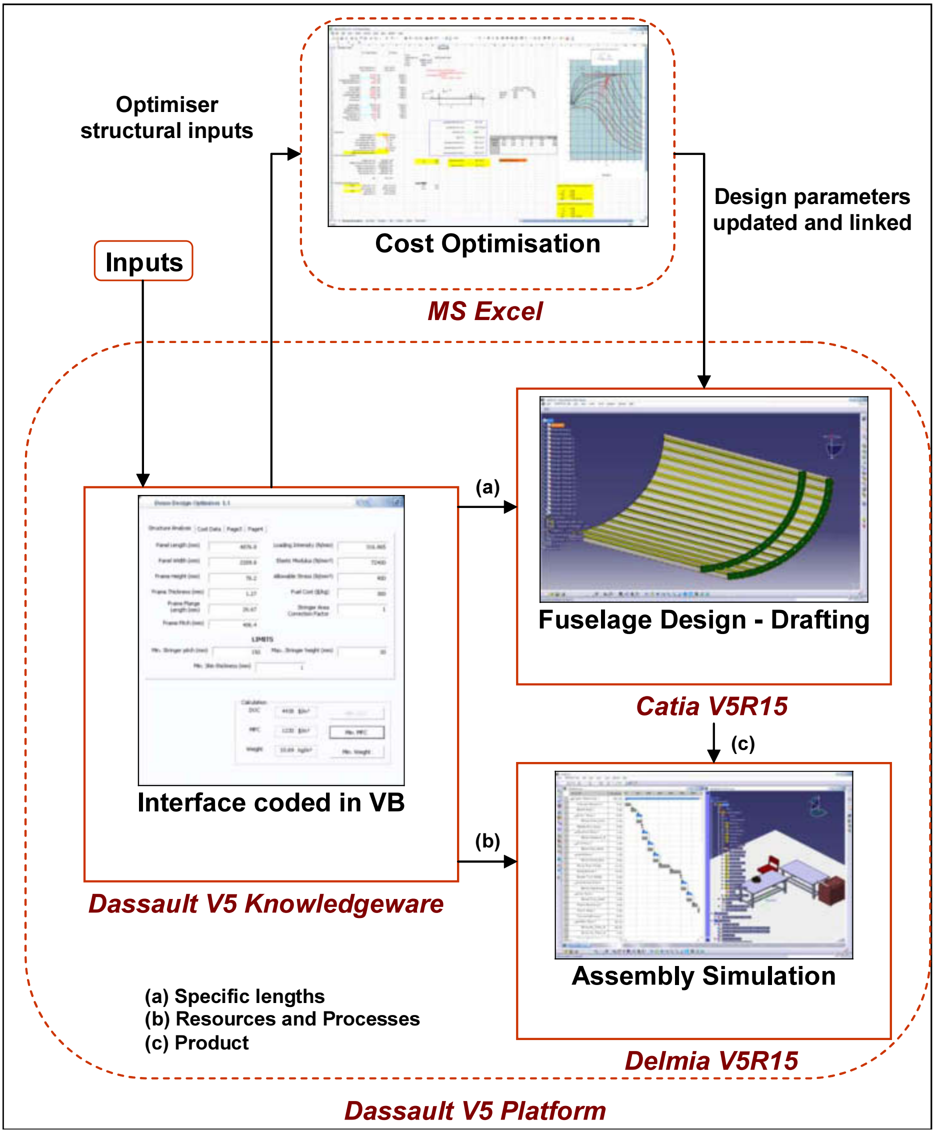


Figure 4. Optimization flow diagram

3) Before considering the final stage in the methodology, a supplementary stage is any final manipulation of the design using the Visual Basic Interface that is launched from the V5 Platform. This offers the possibility for the user to vary input parameters in order to improve the modelled design solution according either to the geometric, loading or cost definition. Geometrically, the visualisation offers the user a creative freedom to 'play' with global parameters which have a crucial role in constraining the design space. Additionally, input cost parameters are also crucial in defining realistic cost computations, whether at an absolute or comparative level. A Results Report can be accessed in order to consider any final alterations such as the amount of limit stress,

panel length, labour cost, etc. A further extension of this could be a sensitivity or uncertainty analysis to further facilitate the human interaction with the concurrent design tool, guiding the designer in the implications of both global and local, parameter and variable, definition.

4) The final stage in the methodology is the passing of all of the information and data generated by Stages 1 through 3 to the Delmia manufacturing simulation platform, as shown in Figure 4. Dassault have provided some functionality within the V5 platform to facilitate the linkage although this is not automated. Primarily the Digital Process Engineer (DPE) module within Delmia was used to generate the Manufacturing Bill of Material (M-BOM) from the consolidated E-BOM from Stages 1 through 3. Once again, the structure of the E-BOM will be different from the structure of the as-built M-BOM, although it will contain all of the constituent parts. The M-BOM is used then to define the process steps and associated resource utilisation for the detailed manufacturing optimization. The work presented in the paper then utilised the Quest module within Delmia, optimize the network flow of the work, relative to resource efficiency, cycle time and overall cost, as set out in the Results Section.

5) The final stage in the methodology is the potential manual manipulation of input variables in light of the results from Stage 4. This manual iteration has not been automated as it is a matter for the creative freedom of the engineer, relative to a complex set of criteria that will vary from case to case. Therefore, the methodology that drives the tool is concurrent with regard to being able to consider both design and manufacturing factors at the one point in time very early in the process but steps back from being over prescriptive, leaving over major decision points to the users discretion.

3.2 Finite Element Analysis (FEA)

In order to compute a Finite Element Analysis (FEA) from this experiment we build a surface model of the panel, shown in Figure 5, and apply a material with the same mechanical properties as the real specimen. The solver calculates the eigen values of the stiffness matrix and gives the different buckling factors (eigen values) for the buckling modes selected. It is assumed that the loading is conservative, then the loading matrix is symmetric. The FEA finds values of λ which lead to singularities in the tangent stiffness. The eigenproblem is posed as follow, with $[K_0]$ the stiffness:

$$([K_0]+\lambda[\Delta K])\{V\}=\{0\}.$$

In order to use 2D meshes, the model has to be defined using surfaces only. However, this type of geometry cannot be made of only one surface; it has to be an assembly of several surfaces. A common mistake would be to joint the several surfaces in the Generative Shape Design workbench; this type of model would give a correct answer if used in a static analysis but not in a buckling analysis because the connections defined in the workbench are not taken into account.

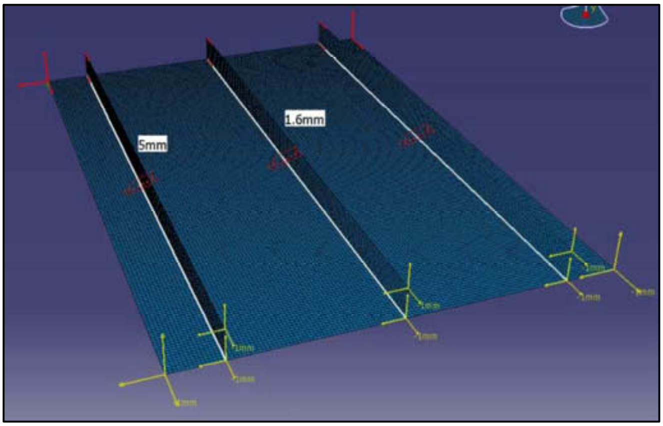


Figure 5. Panel Model in CATIA with deflection input

Then in order to model a 2D panel, Analysis Connections have to be declared in the Generative Structural Analysis workbench for each couple of surfaces. For the simulation used in this chapter, four surfaces have been modelled: one for the skin and three for each stringer. Therefore three rigid connections have been declared between each stringer and the skin. This has to be considered carefully and properly coded when it comes to integrate the Finite Element Analysis (FEA) in an automated process since it requires engineering knowledge to define the correct connections.

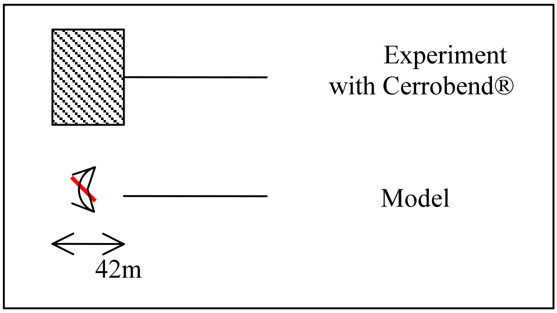


Figure 6. Experimentation Modelling

The following assumptions have been made for the simulations:

- On each side of the panel, Cerrobend® is cast in order to hold the specimen. The panel length is reduced by 42mm on each side in order to model this (Figure 6).
- The panel is simply supported; out of plane buckling is prevented for the skin, not for the stringers.

Once the surface model is built inside the platform, boundary conditions, forces and type of analysis have to be declared. The boundary conditions are not the same depending on which kind of solution is to be found:

- The theoretical results imply simply supported panel as described above.
- The experimental panel is maintained with Cerrobend®, which prevent rotation on the loaded edges. Therefore an extra boundary condition - removing rotation about x-axis on each side of the panel - is added in order to model the actual experimental conditions.

The forces input can be setup in two main ways in order to obtain a buckling solution:

- A compressive load can be applied on one edge of the panel and the critical loads are directly obtained by multiplying it by the buckling factor.
- A deflection can be applied on one edge of the panel, and by computing a static analysis the reactions loads are obtained and scaled by the buckling factor to give the critical buckling load.

These two different approaches give different solutions, and each of the method will be assessed during the mesh convergence study. Indeed, in order to get a correct answer the mesh size should also be studied so as to run the full panel simulation with a good resolution, and therefore gaining time by having directly a proper mesh size.

In order to get a user friendly optimization workspace it is better to declare the geometric parameters used in the optimization during the 3D creation step. In our case we optimize four parameters, namely the skin thickness t, the stringer thickness ts, the stringer pitch b and the stringer height h. The thickness parameters t and ts are properties of the mesh used for the skin and the stringers. Other parameters needed for the optimization are the mass per unit surface of the panel and the allowable stress. These parameters are created using the Knowledgeware formulas editor.

When the Buckling Analysis Case is created, a global sensor displaying all the buckling factors for each buckling mode computed is simultaneously available in the specification tree. The sensors provide parameters (a list in our case) that can be reused in Knowledgeware in order to set rules, checks, formulas and that can be reused in the Product Engineering Optimizer workbench. The final step is to link all the parameters within the optimization interface as input parameters and constraints. Only sensors defined in a mono-occurrence solution can be used with the optimizer, which is why in order to give to the optimizer the right value of buckling factor at each iteration step, we need to pick up the parameter from the analysis results category in the dictionary and not from the pre-processing entity. The correct spelling to get the first mode buckling factor will then be:

bucklingfactors(`Finite Element Model.1 \ Buckling Case Solution.1`).GetItem(1)

During the optimization, the stringer pitch changes and therefore the mesh density between two stringers is adapted. In order to keep a sensible number of nodes between two stringers as discussed in the next section, we link the mesh size with the stringer pitch.

4. Finite Element Analysis and Analysis

4.1 Finite Element Analysis (FEA)

In this part we test several mesh types with varying sizes on a flat plate representing the area between two stringers. The study also takes into account the type of input given to the solver, a displacement or a force. Two types of elements are tested; linear quadrangles (QD4) – first order elements – and parabolic quadrangles (QD8) – second order elements. The first buckling mode is computed for each configuration. The skin allowable stress is calculated using the plate buckling formula, presented in Timoshenko and Gere [15]. The buckling coefficient k is a function of the plate aspect ratio and the plate loading [16].

Therefore, using $k = 4.0$ (a/b is large) and $t = 1.6mm, b = 140mm$, we obtain:

$$\sigma = \frac{k\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{b}\right)^2$$

$$\therefore \sigma = 3.41\times10^7\,N.m^{-2}$$

Therefore the critical buckling load is given by:

$$F = \sigma t b$$

$$F = 7638.82N$$

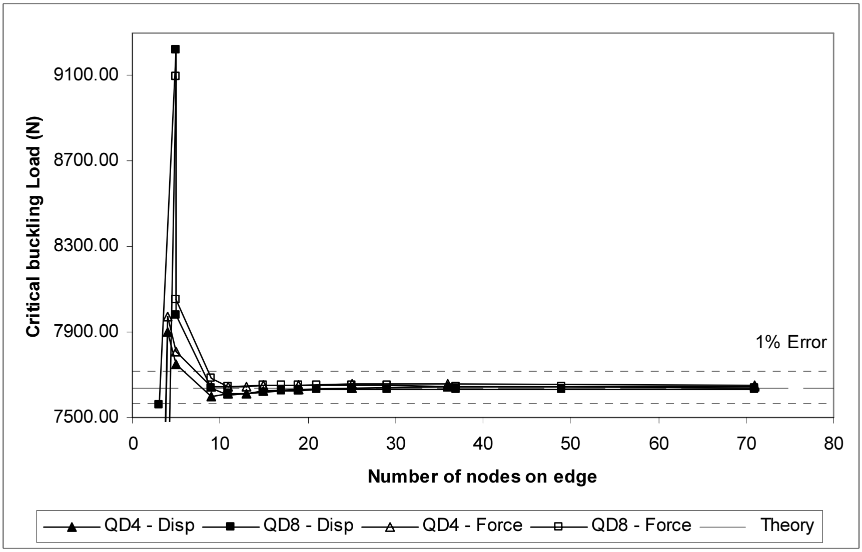


Figure 7. Mesh Convergence Study

The results from the study are displayed on Figure 7. Both QD4 and QD8 elements converge for 10 nodes on one edge without any clear difference. The effect between using a force or a displacement as input is also not clear at this stage.

The step in accuracy just before 10 nodes per edge is significant and will have to be taken into account when it comes to choose the level of accuracy needed for the study.

By checking Figure 8 below it can seen that there are no significant differences in computational cost between QD4 or QD8 elements whatever the method used – displacement or force. Using 10/15 nodes per edge gives a computation time of about 0.1s which is acceptable for an eventual optimization using FEA results.

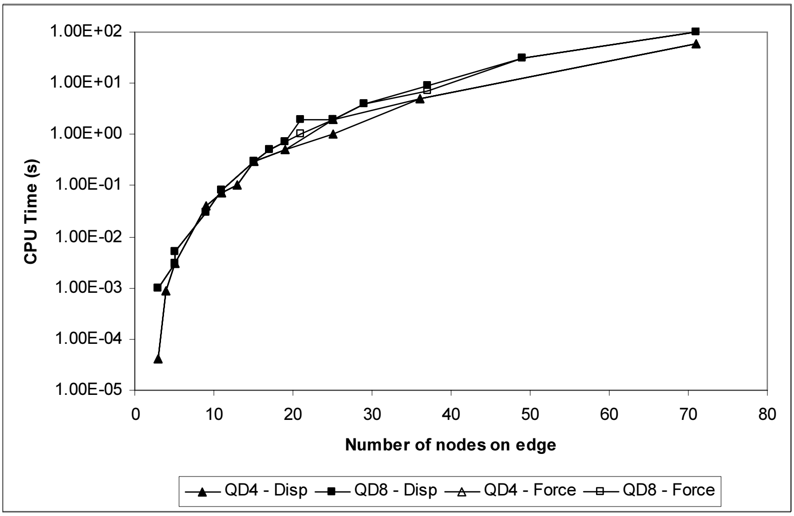


Figure 8. Convergence Time

By increasing the number of nodes per edge from 5 to 10, the result can be improved by 20% and costs approximately 0.07s increase in computation time. However by increasing the number of nodes per edge from 10 to 20, the accuracy can be improved by 0.4% but it costs at least 0.5s increase in computation time.

This study is using values for the critical buckling load of the first mode computed, which is characterized by 4 half-length waves on the skin. In the panel case, because the stringers improve the stiffness of the skin locally, we find 5 half-length waves. We would need then to do the same study for the mode 3 given by the FEA since in this mode we would have 5 half-length waves. This is a 20% difference in wavelength, but being aware of the step in accuracy before 10 nodes per edge given by figure 7, we can assume that 15 nodes per edge will give sensible results. The second order elements – QD8 – give a smoother answer, as seen on figures 7 and 8, which would be better to capture the transition from 4 to 5 half-waves.

Figure 9 gives more information about the behavior of the response depending on the input: distributed force or displacement. Using a distributed force tends to overestimate the critical buckling load whereas using displacements as input tends to underestimate it. From a safety point of view it would be better to use displacements as input since it introduces a safety factor in our results. Then, the use of distributed forces and displacements has got a non-negligible impact on the results and should be investigated further.

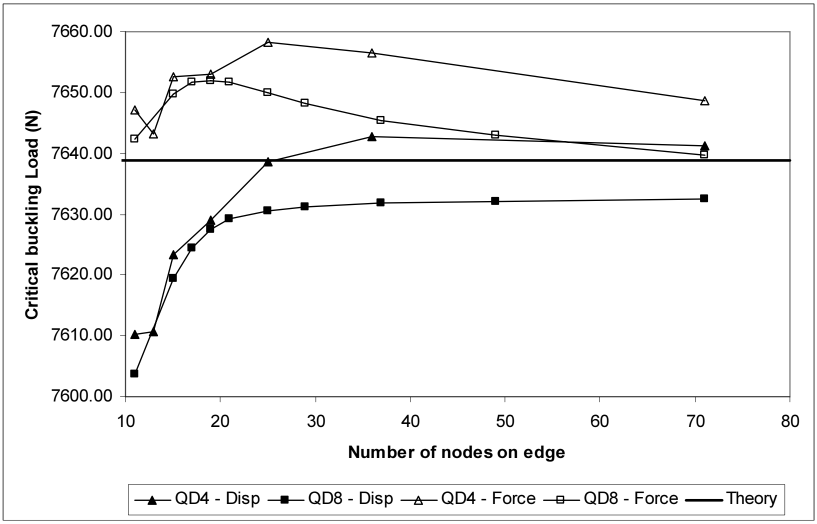


Figure 9. Mesh Convergence Zoom on 1% Error Zone

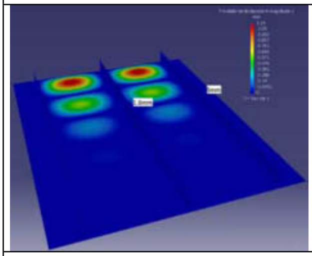
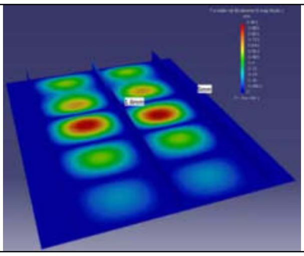
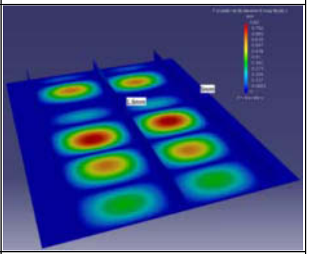
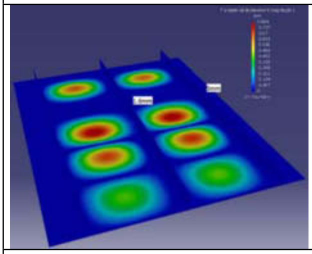
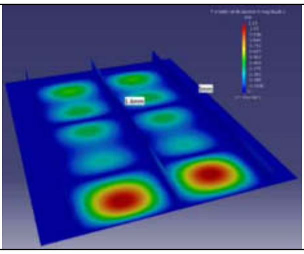
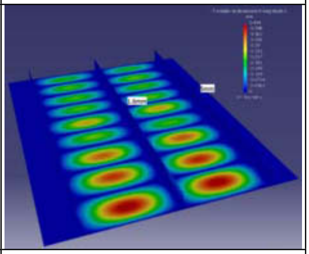
Mode 2	Mode 4	Mode 6
		
51.622 kN	58.202 kN	64.183 kN
Mode 8	Mode 10	Mode 12
		
70.626 kN	72.535 kN	81.446 kN

Figure 10. Modes of vibration

4.2 Distributed Force as input

When using force loaded edges to compute the local buckling load at which first buckling occurs, inconsistent waves are produced. The first 12 modes of buckling are captured using a relatively fine mesh (1.5mm), the results being shown in Figure 10.

The buckling waves obtained with this analysis are not representative of what would happen in reality. Indeed the deformation tends to have a square shape in reality. The only mode having this type of pattern is mode 8. However, buckling waves are not well established over the whole panel, and even if the critical buckling load found using this mode is close to the experimental one it cannot be taken as a sensible result since the analysis does not reproduce reality at all. Therefore using a force as input should not be used to obtain a critical load and then optimize a design within the Dassault Platform.

In the next part of the study we set a displacement as input, which should solve this incoherent waves problem.

4.3 Displacement as Input

This time we apply a forced displacement – say 1mm – on the edge of the panel instead of putting a force. Then in order to compute the critical load we apply the same displacement in a static analysis and scale the resulting reaction force with the buckling factor.

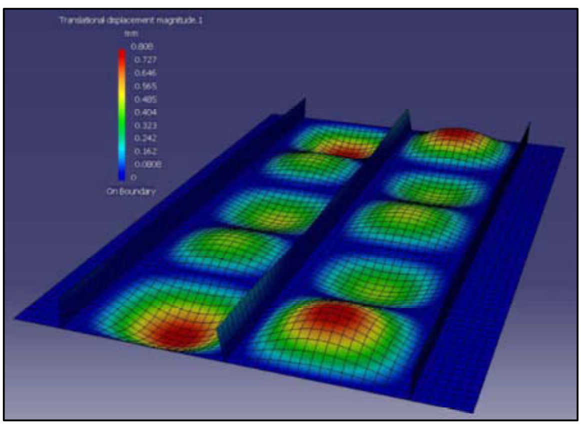


Figure 11. Buckling Displacement Magnitude with an 8mm mesh.

When using this method the buckling waves obtained directly from the first mode match exactly the experimental one as shown on Figure 11. All the modes present a set of coherent waves taking place in the whole panel length and having square shapes just like what can be obtained during the experimental tests. From a practical point of view, a reaction sensor has to be created within the Static Analysis Case in order to obtain the reaction forces in the Generative Structural Analysis workbench. By selecting the restraint wanted, all the reaction forces are automatically computed, using the formula:

$$F = \frac{EA}{L}\delta$$

where δ is the displacement.

4.4 Results

According to the results obtained from the mesh convergence study we compute the full panel case using different mesh sizes in order to fully validate the results from this previous study. The only parameter that varies is the mesh density. Figure 12 shows the results from these consecutive computations. The experimental value is well approximated as soon as we reach 10 elements between 2 stringers as predicted by the mesh convergence study. It was also right to consider refining the mesh and taking 15 nodes per edge on account of an increase in the number of buckling waves in the skin when simulating the full panel. The results obtained by simulation for the experimentation case are about 19% beyond the experimental critical buckling load. This is because the material imperfections are not taken into account for such an analysis but play an important role in the real case. The cost of the simulation is compatible with an optimization use since a 15 nodes per edge computation takes approximately 2.5s with our configuration.

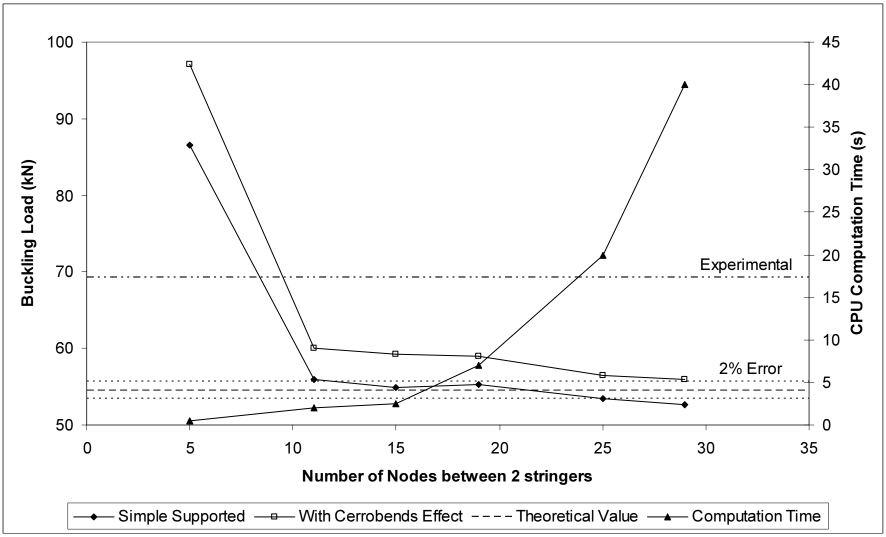


Figure 12. FEA on full panel

4.5 Conclusions

In order to get consistent results throughout the study displacements should be used as buckling input. This will result in obtaining consistent waves and an underestimated critical buckling load including a safety factor. Using a 15 nodes per edge QD8 mesh, we get theoretical results well-approximated, within a 2% error band. However all the experimental results are underestimated, which could give us an already computed safety factor for a panel optimization design. The mesh convergence study gives us the number of nodes per half wavelength needed to capture a buckling phenomenon on a flat plate or a panel. In a case where the number of waves is known, the best mesh size that would fit the study could therefore be approximated. If we suppose that the deformations are square, the following formula gives an approximation of the number of local waves in the skin:

$$\frac{SkinWidth}{SkinLength} = 3.66$$

This can be rounded to four waves on the skin we used, which is the result we obtain for a flat plate of same dimensions in the mesh convergence study. Of course this number of waves gets higher when stringers are used since the stiffness of the skin is increased and then the deformation will be narrower, and more squared shapes can fit in the plate length. In this case the mesh density has to be increased in order to be sure to capture the wavelength transition. However, good practice recommends making a mesh convergence study for any different type of shape used.

5. Optimization and Results

The Product Engineering Optimizer, one of the V5 Knowledgeware modules gives the possibility of linking any parameters and optimising a design for a given output – minimum, maximum, target value or constraints only.

5.1 Optimization Setup

The panel will be optimized to get a minimum mass per unit of surface and resisting to a compressive loading intensity of 300 N/mm without buckling locally. Another constraint specified within the optimization workbench is that the compressive stress is below the material allowable compressive stress taken as 400 N/mm^2. The constraints are the following:

$$\frac{\text{Comp. Stress}}{\text{Crit. Buckling Stress}} \leq 1\,;\, \frac{\text{Comp. Stress}}{\text{Allowable Stress}} \leq 1\,;\, 0.1 \leq \frac{h}{b} \leq 1\,;\, 0.75 \leq \frac{ts}{t} \leq 3$$

The last two constraints define our study in the same range of parameters as the ESDU 70003 [13] study.

The precision of each constraint estimation can be specified at the bottom of the interface. A weight is given to each constraint and is used by the optimizer to rank them depending on their priority to be satisfied. In order to get a converged solution we set a weight of 2 on the constraint defining a level of stress below the critical buckling stress. Indeed this constraint is the most important in our study since we do not want to have a panel that could go into a local buckling mode. The analysis of the optimizer considers two main parameters: the algorithm used and the number of iterations without improvements.

5.2 Analysis of the Optimization

Using a gradient algorithm is not satisfactory in our case since a large number of iterations are done in order to examine the design space gradients as a preliminary computation. A way of tackling this problem is to draw a Response Surface giving a second order equation for the behavior of the buckling factor in function of the geometric parameters and use this equation with a gradient method. However this type of solution is not compatible with a totally integrated tool. That is why we use a Simulated Annealing Algorithm - a Monte-Carlo global minimization technique - to solve the optimization problem. Several convergence speeds can be used with this kind

of algorithm: infinite, fast, medium and slow. These four configurations define the level of acceptance of bad solutions [17]. We compare the answers given by the optimizer for several algorithm speed and different numbers of iterations without improvements. Because the simulated annealing algorithm is a genetic probabilistic meta-algorithm, two successive optimizations with different input parameters can lead to different solutions. In order to take this random aspect of the optimization into account we will run 10 optimizations with random input parameters for t, ts, b and h.

So as to compare the different set of parameters a fast statistic method has to be used. However a Design of Experiment (DOE) method such as the Taguchi Method [18] would not give any interesting answer since it doesn't take into account the randomness of the answers given by the genetic algorithm we use. Different types of multiple comparisons tests can be processed using statistical software. We use JMP 6 in this study to run a Turkey-Kramer HSD (Honestly Significant Difference) test. It provides a test that is sized for all differences among the least squares means and a visual comparison of group means using circles as well as a result table summarizing the whole study [19].

5.3 Results and Discussion

We study eight different configurations of the optimizer: the fast and slow convergence speed with 2, 5, 10 and 15 updates without improvements as convergence constraint. The Turkey-Kramer study results are displayed on Figure 13. The thick grey circles represent the groups that are different from the selected red circles. Therefore we see that 2 and 5 updates without improvements is not enough to get a fully converged solution with a Simulated Annealing Algorithm. The best answer is given by a slow converging optimization with 15 updates without convergence, however as seen on Figure 13, this optimization is the most expensive. The fast converging, with 5 updates without improvement case is part of both groups, with a difference of 3.87kg in the mean values compared to the best results, which is a significant difference in our study case.

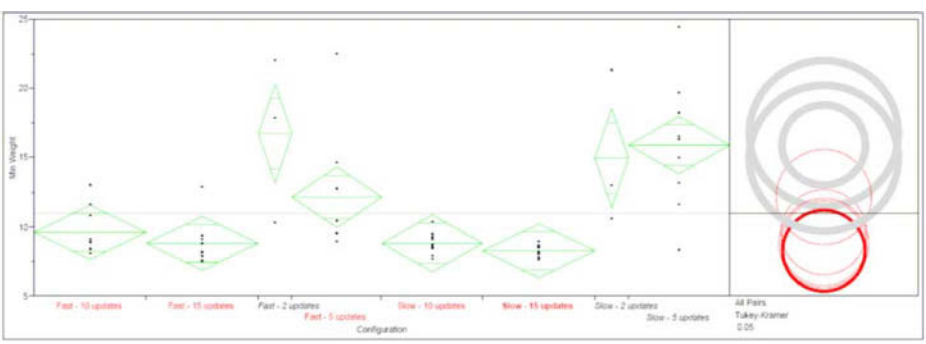


Figure 13. Turkey Kramer Analysis Results

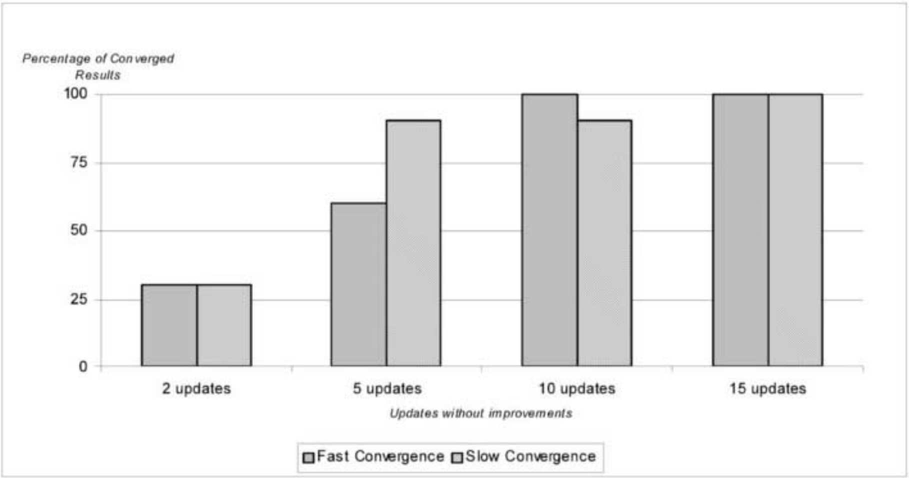


Figure 14. Optimization Accuracy

It has to be highlighted that a theoretical optimization using ESDU 70003 data and a basic Excel solver – gradient method – gives an optimized mass of 7.7 kg, only 4% from the mean result for the Slow 10 updates without improvement solution. Figure 14 gives the percentage converged solutions for each case, and Figure 15 gives the mean number of iterations needed to get a converged solution. We can find that a 10 updates without improvement setting gives the best compromise between converged cases and time for convergence, whatever the converging speed used. The best optimizer settings highlighted in this study would be a slow converging optimization with 10 updates without improvements. This type of study needs a mean number of 38 iterations to converge and gives a mean value of 8.7kg for the optimized panel, against 8.3kg for the lowest group.

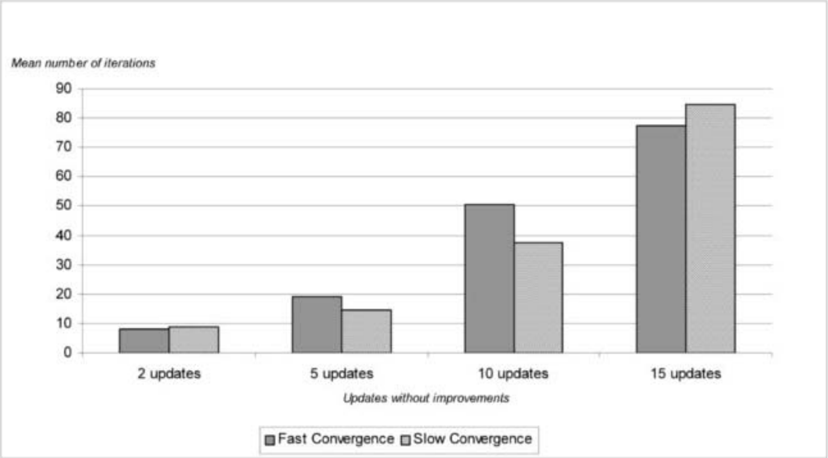


Figure 15. Optimization Cost versus Optimizer settings

6. Conclusions

The paper presents a knowledge driven methodology for the global integration of aircraft structural design based on structural analysis and manufacturing cost optimization relative to weight. The initial design of a fuselage structure is generated from a numerical solution considering the weight and manufacturing cost of the structure relative to Direct Operating Cost. That baseline configuration is then used as the geometrical definition that is analyzed at a more detailed level using the Finite Element Analysis (FEA) method.

The Dassault V5 platform provides a complete toolset for investigating stiffened panel buckling due to a compressive load and their optimization. The computational errors can be minimised and the optimization process is fast: around 40 iterations to get a first answer. The buckling deformation shapes are well-rendered and the theoretical results for a stiffened panel buckling factor can be approached within a 2% error band with a fast computation time which gives the possibility to run an optimization process.

By methodologically processing the wide choice of settings, a fully integrated design and optimization routine can be created and run. Moreover the post-buckling analysis, using non-linear material and analysis procedures could be implemented by adding the commercial FEA package ABAQUS to the Dassault V5 platform. Consequently, the tool facilitates a concurrent engineering approach to the product development phase, both compressing lead time and improving the sharing of relevant multidisciplinary information, which traditionally tends to be carried out in a more serial manner.

7. Acknowledgements

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Integrated Approach for Developing Agile Strategy

Hossam S. ISMAIL, Mark HETHERINGTON

Agility Centre, e-business Division, University of Liverpool Management School, P.O. Box 147, Liverpool, L69 7ZH, UK
E-mail: hsismail@liv.ac.uk *E-mail: mark.hetherington@liv.ac.uk*

Abstract: This paper presents a framework for concurrently evaluating a manufacturing system through examination of turbulent factors affecting the business as a whole. The system then proposes tools and techniques which can be implemented to limit the effect of environmental turbulence, or, to strengthen capabilities which maximise manufacturing performance. The system goes on to assess strategy and suggests whether current manufacturing strategy is relevant and effective when examined through agile perspectives in the current business environment. If areas of weakness are found they are highlighted for attention.

Keywords: Agile manufacturing, agile strategy, Toulmin, QFD, Ishikawa diagrams

1. Introduction

Agile manufacturing is a concept aimed at meeting the exacting demands of today's consumer driven marketplace. Companies must produce products which are highly innovative, first to market, with excellent quality and fast delivery. Small and Chen [1] state 'The basis of competition for manufactured products during the past two decades has shifted from focusing on lower costs to an emphasis on quality, reliability and flexibility'.

Agile manufacturing was first introduced with the publication of a report entitled '21st Century Manufacturing Enterprise Strategy', [2]. Agility was defined here as 'The ability of an organisation to thrive in a continuously changing, unpredictable business environment.'

This paper gives an overview of the Agility Road Map (ARM) framework developed by the Agility Centre at the University of Liverpool, and in particular the process of selecting tools and techniques which help implement agile strategies. The framework assists in providing growth strategy to small and medium sized enterprises through an integrated approach to business improvement. As with Concurrent Engineering it is not one approach but a series of methodologies applied to a business to create a new or modified product or process. The audit system takes on the form of a

QFD model which allows flexibility and delivers a fit for purpose solution. The QFD model facilitates the ease of use of the system and generates outputs from a systemised approach. It utilises 'systems thinking', as well as facilitating cross functional input and generating results which can be easily monitored. Systems thinking is utilised to analyse a complex situation, that of the company and the arena in which it is operating. Systems thinking aims to 'see things in the round, as a whole' but not at 'the expense of missing detail' [3].

2. Evolving agility

The concept of Agility has become one of an evolving philosophy which enables businesses to achieve goals by allowing reconfiguration of processes. Lean was the foundation for manufacturing agility, but the risks of a company becoming too lean is unresponsiveness to customer demands in terms of changes to specifications. To sell products on a truly agile basis a company must have 'products that are easily reconfigurable and upgradeable, fragment mass markets into niche markets, and create continuing rather than single instance sales relationships'. [4]

Agility has also looked to a more integrated approach to solving modern business challenges. This is summarised by agile philosophy, 'flexibility, innovation and customisation on a level previously unknown to organisations' [5]. For a company to become truly agile it must look at all areas of operations and adopt strategies which can adapt to change and respond rapidly to opportunity. 'Agility is broader in scope, that it is not limited, like most flexibility attributes, to the manufacturing segment alone' [6]. Agility started as a concept to be applied to a plant or to a product range, it was seen as a tool to be utilised for gains in a product line. It has since become much more of a strategy and business philosophy which can be utilised even more successfully when applied to the whole value chain. The following gives an example of this: 'The plant manager at one car plant stated that if successful, mass customization would potentially save in the region of $3500 per vehicle due to the elimination of waste, most notably inventory, throughout the supply chain.'[7]. Here mass customisation was to be achieved through implementing agile practices.

3. Overview of Framework

The diagram shows the Agility road map framework, a comprehensive system for agile implementation developed by the Agility Centre at the University of Liverpool. The agile manufacturing concept has been developed by 'placing practical manufacturing requirements at the centre of agility strategies' [8]. The approach has been applied to a number of SME's in the manufacturing sector.

The main objective at this first stage is to 'capture knowledge and data from the company which may be tacit and hard to quantify' [9]. This is done through a series of questions relating to the environmental turbulence that the company is facing then analysing the turbulence fro ability to control and change.

Once the turbulence has been assessed a focus tool is applied giving targets for areas of improvement, this also gives measures and indicators to monitor the effects of any tools and techniques applied. The tool selection and focus are covered later in the paper.

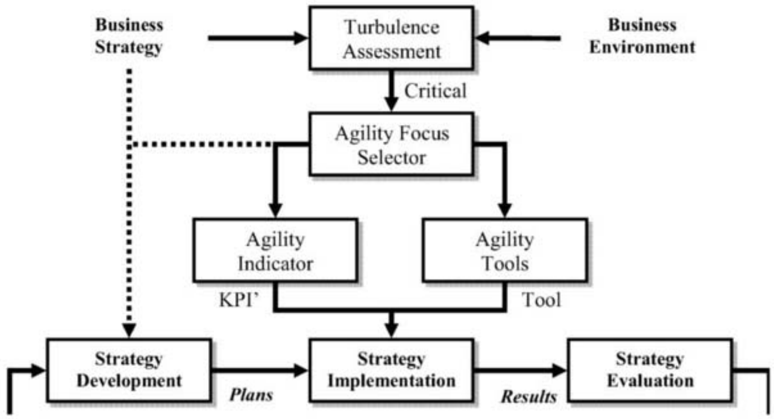

Figure 1 The overview of the agility road map

The final section in the agility framework is the development, implementation and evaluation of manufacturing strategy. This process involves some continuous revision to align strategy with current market requirements, company capabilities and many other factors. It also starts at the development stage as many SME's do not have a formal strategy in place. '(Strategy is) a direction, a guide or course of action into the future' [10]. This is why although a complicated and oft discussed area it must be included in the full framework. The manufacturing strategy must be aligned with corporate strategy or disaster waits when parts of the same company pull in different directions.

4. Agility focus through cause and effect

The sub sections of the Environmental Turbulence Questions from the ARM have been used to identify an agility focus. The focus takes the form of a cause and effect analysis or Ishikawa diagram. The cause and effect analysis is a useful tool to gain a structured approach to problem solving, 'it helps visualise the problem, encourages divergent thinking, and gives a framework in which to operate' [11]. The Ishikawa diagrams were developed in two stages; this allowed greater understanding of how capability indicators, defined in the ARM framework, affected each sub factor. The 'bones' or the branches of the diagram are those categories of performance indicators as defined by Ismail et al as 'Product, Process, People, Operational and Organisational' [8].

The first stage in the diagram development was about including any cause which thought to influence the sub factor (in this case changes in manufacturing), then splitting the causes into the four categories as outlined above. After the first diagram had been developed it was examined as to how the 'causes' map onto the Agility Capability Indicators (ACI's).

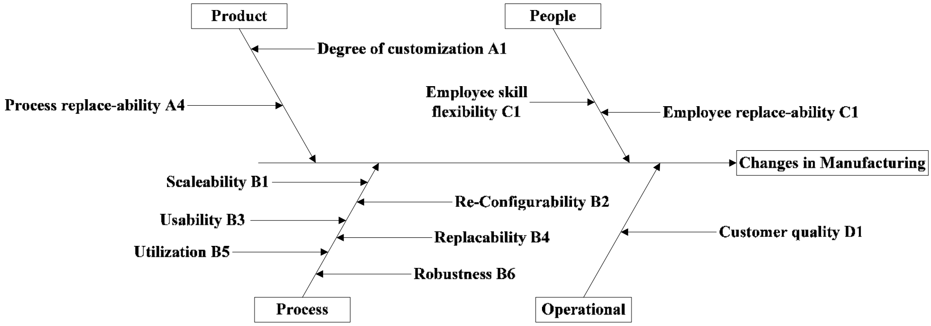

Figure 2 Ishikawa Changes in manufacturing, subsection changes in STEEP

Each capability indicator has a measurement attached to it which allows monitoring of the effects of any changes in the company. This allows some benchmarking and gives an indication to whether the agility focus should be on products, process, people or operations. Using the Ishikawa for mapping cause and effect between the ARM sub factors and the ACI is a recognised key function of this type of diagram. 'The Ishikawa chart (fishbone diagram, cause-effect diagram) is a qualitative tool for summarizing the results of cause-effect analysis' [12]. It can be seen in this example that process is the most populated branch on the diagram; therefore we can say that this is where agility focus is needed. The next stage in the ARM is to identify a set of manufacturing tools which will positively impact on the ACI identified.

5. From capabilities to tools

Once key ACI's have been identified for a company's unique situation a tool selection process is used. The ACI have been examined along with their associated metric(s) to asses the impact of many 'Best Practice' tools. The impacts of tools have been studied from text and case study examples, as well as drawing on personal experiences. The 'Best Practice Folder' which accompanies the ACI and ETI system outlines how some of the tools may be effective in creating a positive change toward agility. Each Ishikawa diagram was examined in turn and an explanation for the placement of ACI on the branches was produced. This was explained in terms of the effect it would have on the sub factor. In the example given above capability B1, Scaleability, was placed on the Ishikawa as changes in manufacturing will be affected by how scaleable the process is during times of high demand. If the process is to be agile then it must able to ramp up or down production to suit. Areas which affect the Scaleability of a process are then examined, some reasons put forward may be: set up and tear downs, the number of breakdowns skill level required.

Tools are then suggested which would have a positive impact on these areas; some suggested for the above example are SMED, OEE and staff multi-skilling. These were then added to the tool selection table for the ACI B1 Scaleability. The process was validated through Toulmins theory of logic, see section 6.

Each tool and technique added to the table was given a rating of High, Medium or Low. This relates to the effect the tool has on the capability indicator and not the ease of implementing the tool. There is no mathematical process for assessing the rankings,

they were added through the validation process when researching case study material. There may be a further process required here for the ranking procedure to be validated but it is not meant to be rigid rule, merely an indication of expected results. It also serves to highlight where some further work may be needed if capabilities have few tools to influence them. While the validation process was being carried out it became apparent that there may be some capabilities which may become affected negatively by tool application. The high medium and low ranking is used in the same way as above to warn the operator of the possibility of this effect.

6. Formalisation and validation of tool selection

Once a tool selection table had been put together the selection of tools was validated using Toulmins theory of logic. This is a system which allows justification of data in a structured approach by providing evidence to support a claim. The diagram below, summarised from Toulmins book, briefly details the approach [13]:

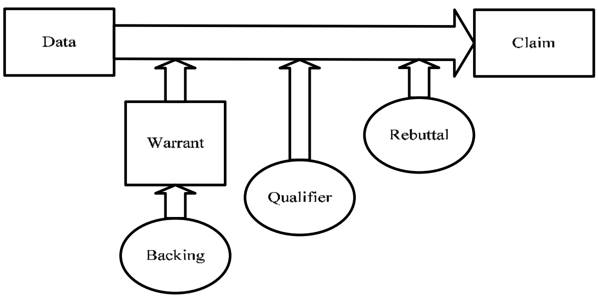

Figure 3 The Toulmin process

Stephen Toulmin is a modern English philosopher who was interested in the role that argument played in rhetoric. He was also a respected expert on the idea of argument and the structure that it takes. He has published two books relating to the subject, ‘The Uses of Arguments’ (1958) and ‘Introduction to Reasoning’ (1984). His argumentative techniques are based on the process of reasoning; logical reasoning asks readers to draw conclusions from relevant, sufficient and representative evidence. ‘Through Toulmin's understanding of the natural, rational thought process of the human mind, he was able to formally give a title to the natural progression of argument. He broke the barriers of inductive and deductive reasoning’. [14]. Toulmin reasoned that by following this process all counter arguments could be answered using evidence or data to back up any rebuttal. It also allows for a great range of data to be taken into account to produce results, the addition of a qualifying statement allows for scenarios where the claim may not be true. ‘If our challengers question is, ‘what have you got to go on?’ producing the data or information on which the claim is based may serve to answer’ [15]. He also goes on to explain that the process takes into account one off situations or anomalies.

For the validation of the tool selection table, case study evidence was used for the data, the claim was that the tool affected the agile capability. The warrant and backing are researched from tool definitions and implementation situations. The rebuttal was

formed from instances where the technique did not produce the expected results. The Toulmin process shows how tools can be implemented successfully and when tools fail, there is usually a reason other than the tool is unsuitable. There will always be exceptions to the rule, this is also why the tool selector table does not produce one tool for each ACI; the operator must take into account company skill level, man power and structure. This highlights the human element in business process improvement; often touted as the most important factor.

7. Tool selection in the Agility QFD model

The tool and technique selection process is part of a larger system with similar parts. These are summarised in the QFD format in Fig 5.

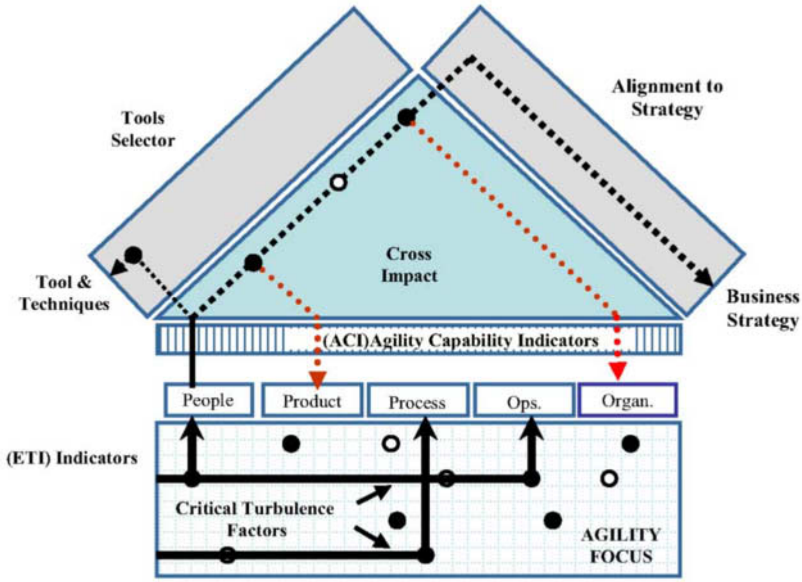

Figure 4 The QFD representation of the agility road map process (Ismail H.S, Christian C, 2000)

The figure shows the critical factors (from the turbulence analysis) feeding into the bottom of the framework, these go through the agility focus matrix producing the output of ACI which are used for measurement purposes in the company. The ACI feed into the tool selector table which outputs the tools and techniques discussed in section 5. On the right hand side of the QFD, strategy selection from a list is shown; this is a development section of the system. It is proposes that there will be an evaluation of existing strategies and a strategy development process. This may work in a similar way to the tool selection table with business environment factors (and others) being taken into account. The QFD methodology for grouping the tool and strategy selection tables allows for some cross impact of variables and clear visualisation of the inputs. It also helps to reduce the risk of mistakes through formalising the process path taken. QFD has also proven useful in business process re-engineering type exercises in the past and so is proposed a best practice methodology. ‘QFD structure and methodology have

been traditionally been used when designing or redesigning a product or service. QFD is also very useful when designing a process or group of interactive processes' [16].

8. Strategy formulation and evaluation

The ARM is not intended to be entirely reactionary to external pressures, it can also be used to aid decision making when planning ahead. If a company is planning future expansion, looking at an Extended Ansoff Matrix type diagram (shown in figure 5), it can be used to address the expected internal pressures emerging from growth. The matrix analogy is used here as an example of planning moves into different business areas. 'The Ansoff Matrix provides the basis for the objective setting process of a business, and it lays down the foundation of directional policy' [17].

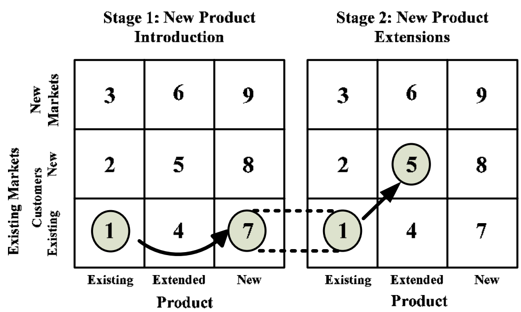

Figure 5 The extended Ansoff matrix for growth strategy (Ismail H.S 2000)

The system outlined in this paper is aimed at strengthening a company's capability to deal with pressures and exploit new opportunities, thus embodying the agile philosophy. 'Agile manufacturing is a strategy aimed at developing capabilities, the emphasis is on designing the enterprise as a whole' [18] The QFD framework highlights different tools and strategic iterations depending on the quadrant of the matrix the company is working in, this is due to the market demographic shift from one section of the matrix to another. The planned growth element makes the ARM a more concurrent process by enabling different section of the business to interact and plan a structured move forward. Within an SME, marketing and manufacturing may not be two discrete areas but the same concept still applies, by planning marketing and manufacturing functions concurrently, future problems with delivering promises can be avoided. 'Both functions must have a common understanding and agreement about the company markets. Only then can the degree of fit between the proposed marketing strategy and manufacturing's ability to support it be known at the business level'. [19]

9. Conclusions

The process of agility is a constantly changing and evolving philosophy. The system developed here takes into account many factors affecting the business on all levels; it aims to produce a strategy and tool implementation plan designed to fit by considering all parts concurrently. The study demonstrates the use of concurrent engineering in

business process improvement and agile implementation. It shows that the risks of failure are minimised and the suggestions for improvement have a better fit in the company's current and future markets. The process has been applied to a number of SME's with varying degrees of success and reduces the amount of time a practitioner needs to spend gathering information in a company. The process of data collection and reasoning about tools and strategies can be further speeded through computer automation. However, it is not intended that such automation will replace humans but simply designed to aid the process of implementing agility and speed it along by using a guiding framework. The process is designed to be a continuous improvement system and parts of the framework should be rerun at regular intervals to remain relevant and help the company move forward, fulfil demands efficiently, innovatively, reliably and with the future in mind.

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Product Family Design Based on Real Options Valuation

Jianxin (Roger) JIAO, Ching Moi LIM and Arun KUMAR
School of Mechanical and Aerospace Engineering
Nanyang Technological University, Singapore 637820

Abstract. This paper discusses a real options approach to product family design (PFD), in which PFD is modeled as an investment strategy being crafted by a series of real options that are continuously exercised to achieve expected returns on investment. An application of the real options framework to a vibration motor manufacturer is reported.

Keywords. Product family, configuration, design evaluation, real options

Introduction

Developing multiple products based on product families sharing common platforms has been well recognized as an effective means to achieve product variety while maintaining economy of scale [1][2]. The fundamental concern underlying product family design (PFD) manifests itself through the fact that the manufacturer must make tradeoffs between customer-perceived variety offered by the product families and complexity of product fulfillment resulting from product differentiation [3]. It is imperative to assess the value and cost associated with the ability of configure-to-order through various options (referred to as management flexibility) inherent in PFD [4]. While substantial efforts have been devoted to optimal product design, the economic justification of product families has received only limited attention [5].

The general gist of most existing approaches coincides with the traditional principle of capital budgeting that is based on unit costs. As a result, opportunities for cost savings from management flexibility are always missed due to unit cost comparisons [6]. Moreover, typical approaches to estimate costs and values associated with a project are based on discounted cash flows (DCF) analysis, e.g., measuring net present value (NPV). The DCF-based methods assume a priori to embed a single operation, which implies management's passive commitment to a certain operating strategy. Therefore, DCF analysis usually underestimates the upside value of investment [7].

Yano and Dobson [8] have observed a number of industrial settings, where a wide range of products are produced with very little incremental costs per se; or very high development costs are shared across broad product families; or fixed costs and variable costs change dramatically with product variety. They have pointed out that "the accounting systems, whether traditional or activity-based, do not support the separation of various cost elements". The missing link behind is probably the neglect of upside potential contributed by management flexibility of product families [9].

Towards this end, this paper applies the real options theory to the valuation of management flexibility associated with product family configuration design. The use of real options has proven to be an accessible approach for the valuation of certain types of flexibility [6][10]. When using real options for capital budgeting purposes, it is possible to take flexibility options into account in the valuation process [7]. This paper specifically deals with how to measure and evaluate flexibility associated with PFD in accordance with economic considerations. The goal is to present design and process engineers with insights into product customization and its impact on the economy of scale in design and production.

1. Real Options Approach

Under the real options thinking, PFD becomes optimal decision making regarding a portfolio of real options to be exercised at different stages of the design project. PFD generally involves two aspects: (1) product-related options, referred to as technical real options, and (2) project-related options, referred to as financial real options. Technical real options characterize the physical flexibility built in the product families that contributes to the technical performance of design. Financial real options, on the other hand, indicate the management flexibility staged along the project life, which constitutes the justification of profit performance of design. Therefore, the valuation of PFD calls for a hybrid approach combining engineering analysis with financial analysis.

The pricing of options generally depends on the value of several underlying variables and can thereby be seen as a derivative. The value of a derivative can be expressed as certain analytical formulas, such as the Black-Scholes formula [10]. The financial real options associated with PFD, however, possess a complex payoff pattern and are dependent on several underlying assets.

The value of financial real options is thus dependent on multivariate underlying assets represented by the demand of each product. Because the terminal boundary conditions are very complex, it is difficult to obtain an analytical solution to the above expression. There are two types of numerical approaches available: a lattice approach, which also allows for American options, and Monte Carlo simulation, which is restricted to European options.

This research adopts a multivariate binomial lattice approach to the pricing of financial options of PFD. If a lattice approach is used in the case of K product variants, demand at each end node at time T together with prices and cost estimates can be used to find an optimal configuration at each end node. Then, using the risk-neutral probabilities and the risk-free rate, the value of the option at the valuation date can be estimated by working backward in the lattice.

2. Product Family Design Optimization

With PFD real options, configuration design becomes the selection of specific technical real options along with their relevant financial real options. Given a customer order expressed as a set of customer needs, $\{CN_m \mid m = 1, \cdots, M\}$, a few product variants, $\{y_k\}_K$, may be configured from existing product platforms. Each configured product, y_k, is achieved through a portfolio of call options, including a subset of existing

technical real options, $X_{y_k}^T \equiv \{x_r^T \mid r = 1, \cdots, R_{y_k} < I\} \subset \{x_i^T\}_I$, and a subset of available financial real options, $X_{y_k}^F \equiv \{x_s^F \mid s = 1, \cdots, S_{y_k} < J\} \subset \{x_j^F\}_J$. The performance variables of each technical real option x_r^T originate from a subset of original customer needs, i.e., $\{\tilde{F}_{rq} \mid q = 1, \cdots, Q_r\} \subset \{CN_m\}_M$. The objective of PFD is to achieve the overall optimization of the selected portfolio of real options. Therefore, the expected payoff of product y_k is introduced as the objective function, which is defined as:

$$max \quad \mathrm{E}\left[V(y_k)\right] = V^T\left(X_{y_k}^T\right)V^F\left(X_{y_k}^F\right) = \sum_{r=1}^{R_{y_k}} V^T\left(x_r^T\right)\sum_{s=1}^{S_{y_k}} V^F\left(x_s^F\right), \tag{1}$$

where $V(y_k)$ is the payoff function defined for product y_k, $V^T\left(x_r^T\right)$ suggests the technical value of a technical real option involved in y_k, and $V^F\left(x_s^F\right)$ indicates the financial value of a financial real option associated with y_k, which is calculated using the multivariate binomial lattice approach.

The conjoint-based search for an optimal portfolio of real options always results in combinatorial optimization problems because typically discrete functional feature values are used in configuration. Nearly all of these problems are known to be mathematically intractable or NP-hard, and thus mainly heuristic solution procedures have been proposed for the various problem types. Comparing with traditional calculus-based or approximation optimization techniques, genetic algorithms (GAs) have been proven to excel in solving combinatorial optimization problems.

3. Application

The proposed PFD framework has been tested in an electronics company producing mass customized vibration motors for mobile phones. Based on the analysis of historical data on the company's product fulfillment and existing manufacturing capabilities, the vibration motor product platform is constructed and accordingly the associated standard routings are identified. The functional features expressing customer needs and the specifications of vibration motor product platforms are summarized in Table1.

Targeting the low-, medium- and high-end market segments, three respective vibration motor product platforms are established: PdP_1, PdP_2 and PdP_3. Two customer orders are selected for testing purpose: CNA and CNB, representing low- and high-end customer needs, respectively. The specifications of individual customer needs and the product demand distributions in the respective markets are given in Table 1 as well.

Each product platform, for example PdP_3, supports a class of product family design. Figure 1 illustrates the established configuration mechanism within platform PdP_3, whereby product variants are generated by configuring options of variety generation on top of those common modules of the product architecture. In accordance with the identified variety generation methods, PFD real options are defined for PdP_3. As far as platform PdP_3 is concerned, 1 screening real option, 7 primitive technical real options and 4 nesting real options are identified. Considering four types of financial real options in relation to each technical real option, the total number of financial real options for

platform PdP_3 is 48. Likewise, the total numbers of real options associated with PdP_1 and PdP_2 are identified as 5 and 9, respectively. This gives rise to 20 and 36 financial real options for PdP_1 and PdP_2, respectively.

Figure 2 compares the achievements, in terms of the normalized expected payoff, technical value and cost of top 5 product designs for customer CNB in the 299th generation that returns the optimal solution. Among these designs in the population, three ($\hat{y}_1^{CNB}$, $\hat{y}_2^{CNB}$ and $\hat{y}_3^{CNB}$) are derived from platform PdP3, whereas $\hat{y}_4^{CNB}$ and $\hat{y}_5^{CNB}$ are based on platforms PdP2 and PdP1, respectively. Obviously, in terms of an overall satisfaction of CNB, those designs derived from a high-end product platform outperform those based on the low-end ones.

Table 1. Specifications of customer needs and product platforms for market segments

Functional Feature $\{CN_m\}_M$		Individual Customer Needs $[CN_m^L, CN_m^U]$ & $u(CN_m)$		Product Platform (Customer Needs per Market Segment) $[F_{iq}^L, F_{iq}^U]$ & $u(F_{iq})$		
		Customer CNA	Customer CNB	PdP_1	PdP_2	PdP_3
Armature (A)	A1 (Current / mA)	60±15 / Triangular	80±20 / Triangular	[50, 70] / Triangular	[65, 80] / Triangular	[85, 110] / Triangular
	A2 (Pb free)	N / Uniform	Y / Uniform	[Y, N] / Uniform	[Y, N] / Uniform	[Y, N] / Uniform
Frame (F)	F1 (Length / mm)	9.5±3 / Triangular	13.5±4 / Triangular	[8.5, 12] / Triangular	[11, 15] / Triangular	[14, 17] / Triangular
	F2 (Diameter / mm)	10±4.5 / Triangular	19±8 / Triangular	[6.5, 15] / Triangular	[11, 19] / Triangular	[15, 27] / Triangular
Bracket (B)	B1 (Color)	R / Uniform	B / Uniform	[R, W, B] / Uniform	[R, Y, B] / Uniform	[R, B, G] / Uniform
	B2 (Connected Method)	U / Uniform	M / Uniform	[U, X, L] / Uniform	[U, F, D] / Uniform	[U, M, T] / Uniform
	B3 (Coating)	N / Uniform	Y / Uniform	[Y, N] / Uniform	[Y, N] / Uniform	[Y, N] / Uniform
Weight (W)	W1 (Shape)	P / Uniform	U / Uniform	[P, T] / Uniform	[P, T, U] / Uniform	[P, T, U] / Uniform
	W2 (Holding Strength / kg)	4±2.5 / Triangular	5±3 / Triangular	[2.5, 5] / Triangular	[3.5, 6.5] / Triangular	[5.5, 8.5] / Triangular
	W3 (Speed / rpm)	5500±200 / Triangular	10500±1500 / Triangular	[5000, 9200] / Triangular	[8000, 10000] / Triangular	[9500, 14000] / Triangular
Magnet (M)	M1 (Pb free)	N / Uniform	Y / Uniform	[Y, N] / Uniform	[Y, N] / Uniform	[Y, N] / Uniform
Rubber Holder (RH)	RH1 (Color)	R / Uniform	B / Uniform	[R, W, B] / Uniform	[R, Y, B] / Uniform	[R, B, G] / Uniform
	RH2 (Shape)	P / Uniform	T / Uniform	[P, T] / Uniform	[P, T, U] / Uniform	[P, T, U] / Uniform
Product Demand	Increase Rate μ_{CN}	1%	5%			
	Volatility σ_{CN}	0.1	0.45			
	Initial Demand $D_{CN}(0)$	15000	950			

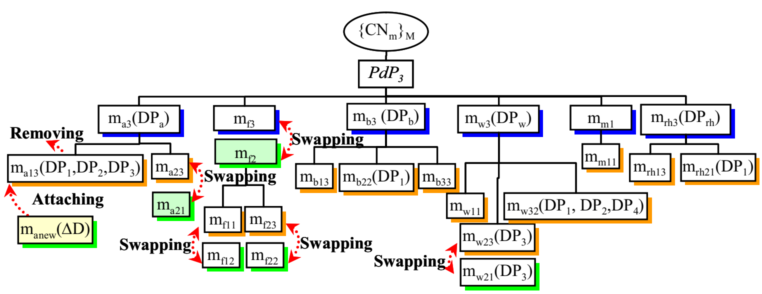

Figure 1. Variety generation within platform PdP_3

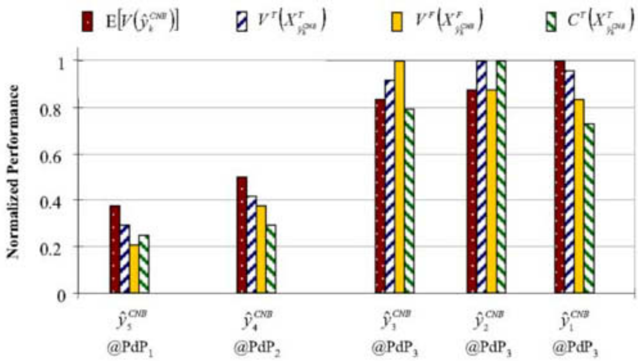

Figure 2. Performance comparison of optimal design population for customer CNB in the 299th generation

It is interesting to notice that the peak of technical achievement ($\hat{y}_2^{CNB}$) does not contribute to producing the best fitness as its cost is estimated to be high. On the other hand, the minimum cost measure ($\hat{y}_5^{CNB}$) does not mean the best achievement of overall performance measure as its technical performance is moderate. Also interesting to observe is that, within the same platform, the worst fitness ($\hat{y}_3^{CNB}$ @PdP$_3$) may not perform with the highest cost figure (it is $\hat{y}_2^{CNB}$ @PdP$_3$ instead). Likewise, the highest technical achievement ($\hat{y}_2^{CNB}$ @PdP$_3$) may not correspond to the best fitness (it is $\hat{y}_1^{CNB}$ @PdP$_3$ instead). The best design ($\hat{y}_1^{CNB}$ @PdP$_3$) results from a leverage of both technical and cost performances.

The PFD strategies differentiate in the fulfillment of customers CNA and CNB using different product platforms. Six product technologies are selected from the GA solutions: CNA@PdP$_1$, CNA@PdP$_2$, CNA@PdP$_3$, CNB@PdP$_1$, CNB@PdP$_2$, and CNB@PdP$_3$. While these technologies involve varying degrees of customization and flexible design, CNA@PdP$_1$ involves the least customization and employs the low-end and almost standard platform. Nevertheless, technology CNB@PdP$_3$ accommodates the most customization with the highest degree of flexibility.

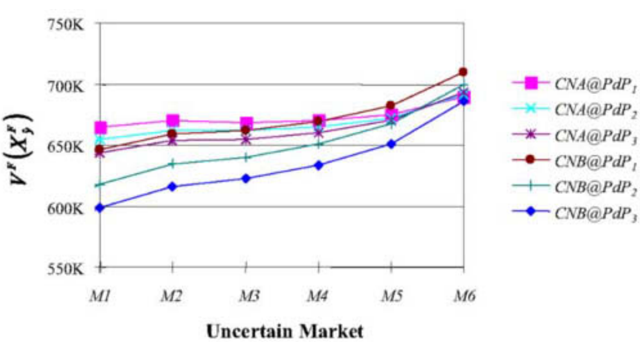

Figure 3. Performance of different technologies with respect to demand uncertainty

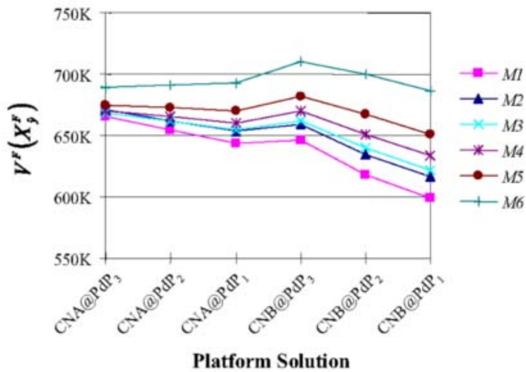

Figure 4. Performances of different technologies under different markets

The results of profit potential for every market-technology pair are shown in Figures 3 and 4. Figure 3 compares the financial performances of these technologies with respect to different market scenarios. It indicates that standard solutions based on less flexible platforms (CNA@PdP$_1$ and CNB@PdP$_1$) tend to outperform those customized designs based on more flexible platforms (CNA@PdP$_2$/CNB@PdP$_2$ and CNA@PdP$_3$/CNB@PdP$_3$) when the market requires low variety and the demand is less uncertain. With the increasing uncertainty in the market, however, the benefit of using less flexible platforms becomes diminishing and more flexible technologies clearly perform better. More flexible technologies demonstrate an increasing trend of good profitability with the increase of demand uncertainty related to variety. This suggests that an over-capacity situation should be avoided in PFD, whereby a high-end platform is used to deal with low-end customer needs. A high-end platform possessing more options usually involves high fixed costs although the variable costs incurred may be moderate.

Figure 4 compares the performance of PFD with respect to six technologies under different production environments. It suggests clearly a local maximum at CNB@PdP$_3$ and M6. This coincides with practical concerns – always seeks for a market with best payoff potential (characterized by M6) while installing most cost-effective PFD capability (indicated by CNB@PdP$_3$). In less uncertain markets, the less flexible technologies (CNA@PdP$_1$ and CNA@PdP$_2$) perform quite well, but as uncertainty increases the flexible technologies (CNA@PdP$_3$ and CNB@PdP$_3$) starts to dominate all the others.

Figure 4 further shows the evidence that the presence of configuring platforms affects system performance quite differently depending on market uncertainty. When variety is low, high cost of configuring a platform causes a flexible design system to perform poorly, even worse than a standard system. As a result, the focus of PFD should be primarily concerned with the charge of configuring platforms if the market involves low variety. A standard base design may perform better in dealing with low variety than a flexible design with high cost of configuring the platform. However, if the market uncertainty is high, the charges of configuring platforms become less critical. On the other hand, in a high-variety environment, a flexible design system, although

involving significant costs of configuring platforms, may be more valuable than a standard system, owing to its low variable cost.

4. Conclusions

This paper presents real options valuation as a practical and effective framework to evaluate product family design (PFD). Through integration of engineering analysis and financial analysis, the procedure clearly recognizes the value of management control and the exercise of choices at key decision points along the PFD project life. It permits a consistent choice of the risk-free discount rate for the valuation, because the project risks can be diversified and the market risks are accounted for by the options analysis. It utilizes the knowledge of the technical and financial experts for the respective evaluation of product and project related flexibility.

An application of the real options framework to the vibration motor manufacturer illustrates the feasibility and potential of the proposed approach. As witnessed in the case study, the implementation of this method is straightforward. Most importantly, this approach leads to significant improvements in the value of PFD by recognizing the value of flexibility either inherent in a project or that can be built in product platforms. These improvements are more promising when uncertain demands are concerned, and when the downstream costs are relatively large.

As far as a PFD project is concerned, the value of flexibility increases, as do options, when there is more risk. This is because the ability to avoid unfavorable circumstances or to take advantage of favorable opportunities is more valuable when there are greater prospects of exploiting flexibility inherent in product platforms. Investing into a PFD project creates options for the company to accommodate future mass customization requirements. The company possesses the flexibility to choose, over the course of developing product families, whether to develop variants based on existing platforms or develop the desired products individually, or to configure the desired products based on many options of platform elements. Flexibility of these real options bestows extra values to the company by hedging against volatility and turbulence in the market, design and production. The valuation of real options thus sheds light on the analysis of value-cost tradeoffs underlying product platforms and family design. Real option models thus deserve a place in toolkits of decision making due to high uncertainty and costs of irreversible investment in PFD.

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Application of Information Theory to the Quantification of Concurrent Engineering Processes

George CHRYSSOLOURIS[1], Eleni VASSILIOU and Dimitris MAVRIKIOS
Laboratory for Manufacturing Systems & Automation, Department of Mechanical Engineering & Aeronautics, University of Patras, Rio, Patras 26500, Greece

Abstract. The paper explores the use of Information Theory for modelling the information exchange and flow in the product development process. The models developed are implemented in serial, as well as in concurrent product development. They provide a qualitative analysis of the messages exchanged through the communication channels and they lead to a comparison of the effectiveness of concurrent engineering to that of sequential. The case study is the pilot implementation of the model, based on information theory, in a bicycle manufacturing company. The results have shown that in the concurrent approach, the total development and detection times of the potential errors are reduced compared with those in the serial approach.

Keywords. Concurrent engineering, information modelling, information theory, information exchange, communication model

Introduction

Historically, the product development process was performed in a highly serialised way within a company. The design process was performed independently from the process planning, resulting in a significant amount of back-tracing, retracing, and long development cycles. Thus, the design process was an iterative and time-consuming process. The "unmanufacturable" elements in a part design were identified by the engineers in the process planning department, only after the final part designs had been completed and transferred to the process planning. Manufacturers often faced the fact of having to make changes on the product during the last stages of production. These changes most of the times, were proven costly and also had negative consequences both on the product quality and on the time-to-market.

In the last years, the growth of international commercial competition and the development of new Information Technology tools have driven to the development and implementation of Concurrent Engineering (CE) methods and tools in the product development process [1, 2, 3, 4]. In CE the product and process specifications are released simultaneously. The design and manufacturing constraints are being

[1] Corresponding Author, e-mail: gchrys@hol.gr

considered from the earliest stages of the design process. Thus, the working groups of the different company departments share and exchange information from the earliest stages of the product development. However, existing approaches of quantifying the information flow and exchange among the departments are primitive. Information Theory (IT) presents a mathematical analysis of communication, making it possible to design communication systems, which most efficiently make use of any available resources.

This paper, describes the development and pilot implementation of methods and models based on IT, which lead to the modelling of information exchange in the product development process among the different departments. Key issues in CE, namely, design of communication systems, measuring the information exchange through the communication channels and minimising the noise are addressed in this paper. Messages transmitted through the communication systems are considered to be, for example, the designs of the parts, which are fully manufacturable. These messages originate at the source and are subsequently transformed by some transmitter into a signal able to be transmitted over the channel. Once the signal has reached its destination, it is then converted back into the original message content. However, the messages in most of the cases contain "distortions" that prevent, for example, the designs from being manufactured. Hence, all unmanufacturables can be considered as manifestations of the noise in the communication system. The quantification of the messages exchanged allows the qualitative comparison of CE with that of the serial approach.

The case study is the pilot implementation of the developed methods and models in a bicycle manufacturing company, which results in the quantification of messages exchanged among the design, process planning, manufacturing, assembly and packaging department. The following section provides the definition of the basic terms used in Information Theory, namely information content, source entropy, channel capacity and duration of the transfer. Furthermore, it describes the model, which gives the analogy between the communication systems and the departments of the manufacturing company. The results of the developed model, being implemented in a bicycle manufacturing company, are presented in Paragraph 2. The total bicycle development time is estimated in both a serial and a concurrent approach.

1. Modelling Approach of Information Exchange in Product Development

Although CE approaches offer substantial benefits and hence many manufacturing companies are beginning to take a strong interest in the collaborative approaches, it is not yet clear how it can best be implemented. In the CE approach, the information exchange among the different departments of the company is a complex process. Therefore, there is a need for a more quantitative understanding of the information exchange, necessary for the design and manufacturing processes of the products.

In this paper, modeling of the information exchange will be based on IT, which provides mathematical models of the communication systems [5]. These models are based upon probabilities, making it possible to design communication channels, which most efficiently make use of the available resources, thus minimising the time for data

transfers. The concepts first presented in IT, namely information content, source entropy, channel capacity and duration of transfer are defined below.

Information content is given by Eq. (1):

$$I(X_i) = \log_a \frac{1}{P(X_i)} \tag{1}$$

where $X_1, X_2, \ldots, X_n$, are considered to be messages in a zero-memory source, and $P(X_i)$ is the probability of the transmission of the X_i message. In particular, the above equation provides the information content each time a message is selected.

The source entropy provides the average amount of information per message selection and is given by:

$$H = P(X_1)\log_2 \frac{1}{P(X_1)} + P(X_2)\log_2 \frac{1}{P(X_2)} + \ldots\ldots\ldots + P(X_n)\log_2 \frac{1}{P(X_n)}$$

$$= \sum_{i=1}^{n} P(X_i)\log_2 \frac{1}{P(X_i)} \; bits\ /\ message \tag{2}$$

where $X_1, X_2, \ldots, X_n$, are the messages included in the source of the communication system. Moreover, the source entropy corresponds to the average amount of information generated by the transmission of messages through the communication system. Thus, when a source generates (N) messages then these can be encoded and transferred using

$$I = N \times H \text{ (bits)} \tag{3}$$

The capacity of a channel, known as its ability to transfer information, is measured in bits/second, or bps and is given by : $C = I / T$. In a noisy channel, this translates into the maximum rate of information transmission. It is important to note that by coding, i.e. the method of encoding a message into a signal and decoding it through the receiver, this capacity can be reduced or enhanced. The duration (T) of the transfer is given by:

$$T = I / C \text{ (min)} \tag{4}$$

In the case of product development in a manufacturing company, a number of messages are exchanged among the departments. For the purpose of this paper, the chain of the departments involved in the product development phase, comprises the design, process planning, manufacturing, assembly and packaging departments (Figure 1).

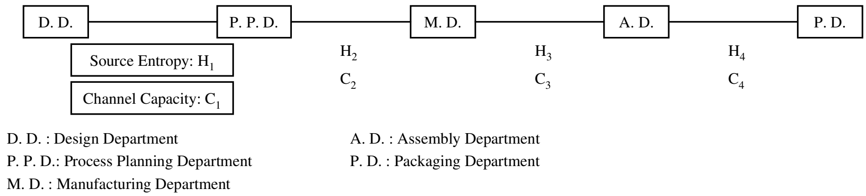

Figure 1. Departments involved in the product development phase

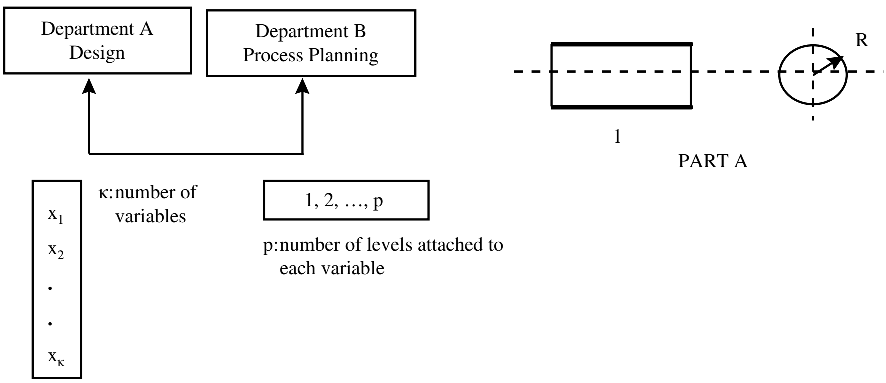

Figure 2. Information exchange between two departments

The implementation of IT in the chain of the departments involved in product development, results in the quantification of the messages exchanged among the departments. For this quantification, there is a need to define the model of this information exchange.

Consider as an example the information exchange between Department A (Design) and Department B (Process planning) (Figure 2). Moreover, consider that the information concerning the design of Part A, shown in Figure 2, must be transmitted.

The designs of the part can be coded with the use of some of the variables shown in Table 1, which are used to describe the geometric and manufacturing features of the part [6].

Since the source includes k = 26 different variables, the source entropy is given by Eq. (5).

$$H = \sum_{i=1}^{k} P(X_i)\log_2 \frac{1}{P(X_i)} = k\left(\frac{1}{k}\right)\log_2 k = \log_2 k =$$

$$\log_2 26 = 4.7 \quad its \quad message \tag{5}$$

Each variable needs an attached number (p), called level, in order to be described. This number (p) corresponds to the number of parameters required for each variable in order to be defined. For the part shown in Figure 2, the coding is *cyl_12*. The code "cyl" is a variable in the source and corresponds to one message. This variable needs p = 12 parameters in order to be defined and each parameter corresponds to a message. Thus, the total number of messages is N = 13 (messages).

In general, the number of messages (N) for a part is given by the total number of variables used for describing the design characteristics of the part, plus the number of levels attached to each variable, which describe the geometric characteristics of each variable.

The information content transferred among the departments is given by Eq. (6).

$$I = N \times H \text{ bits} \tag{6}$$

For the above example, the information content is $I = 13 \times 4.7 = 61.1$ (bits).

Assuming that the channel capacity equals $c = 10$ (bits/min), then the duration of transfer is: $T = I \qquad = 61.1 \quad 10 = 6.11$ (min)

As indicated by Eq. (5), the source entropy (H) depends on the number of variables (k). In particular, as the number of variables increases, the source entropy also increases. The number of levels (p) define the number of messages (N). Both the number of variables (k) and the number of levels (p) define the information content of the transmitted messages. The information content is affected greatly by the increases of levels (p) rather than by the increase of variables (k). Therefore, when defining the variables and the levels in the source, it is better to decrease the number of levels and increase the number of variables.

In the CE approach, several channels can be used in parallel in order for the information among the various departments to be transferred (Figure 3). The channel capacity can be considered proportional to the overlapping of the processes. As shown by Eq. (4), the duration (T) of the transfer is reduced as the channel capacity (C) is increased. The channel capacity of CE is greater than that of the serial approach. As a result, the development time of the product is reduced compared with that of the serial approach.

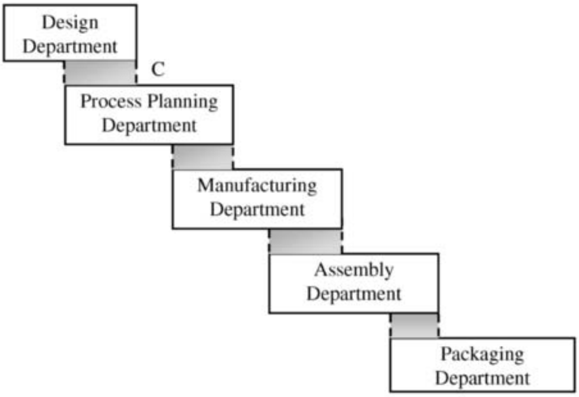

Figure 3. Overlapping of processes in CE approach

The modelling approach described above, will be used to quantify the information exchange among the departments of a manufacturing company. The total development time of the product is estimated, both is serial and in concurrent approach. Using the quantification of the messages exchanged, the effectiveness of the CE product development can be compared qualitatively with that of the sequential.

2. Results and Discussion

The modelling approach described above is implemented in a bicycle manufacturing enterprise, which includes five departments: the Design Department (DD), the Process Planning Department (PPD), the Manufacturing Department (MD), the Assembly Department (AD) and the Packaging Department (PD) (Figure 1). Four communication models are developed which provide the quantification of the messages exchanged between DD and PPD, PPD and MD, MD and AD, and AD and PD respectively.

In both approaches, serial and concurrent, three errors have been considered in the designs of specific parts. The error detection and recovery time as well as the total bicycle development time are estimated in both approaches and are compared.

2.1. Quantification of Information Exchange between the Design and Process Planning Department

The designs of the parts are coded with the use of k = 26 different variables (Table 1). The variables provide information on the geometric, manufacturing features, etc.

Table 1. List of variables included in the Design Department

Geometric features	**Manufacturing features**	**Boolean operators**
P_ (parameter)	thruhole_	extr_ (extrude)
line_	blhole_ (blindhole)	union_
circle_	tapping_	sub_ (subtract)
ell_ (elliplse)	tapthruhole_ (tapped thruhole)	slice_
semiell_ (semiellipse)	tapblhole_ (tapped blindhole)	
arc_	chamfer_	
polygon_	fillet_	
cyl_ (cylinder)	mat_ (material code)	
sphere_		
torus_		
tetrahedroon_		
block_		
cone_		
surf_ (surface)		

A number (p), called level, is attached to each variable and provides the minimum number of parameters needed to specify the geometry of each variable. The number (N) of messages which corresponds to each design of the part, depends on the number of variables (k) and the number of levels (p) attached to each variable. For example, the number of messages needed to describe the designs of the bottom bracket tube is N= 48 (messages) (Table 2).

Table 2. Total number of messages resulting from the coding process of tube

Message	**Parameter**	**No. of messages**
Mat_	2	3
Cyl_	12	13
Cyl_	12	13
Sub_	2	3
Tapblhole_	7	8
Tapblhole_	7	8
Total No.		48

The source entropy is given by Eq. (5), where k=26 and $P(X_i) = 1/26$ since all the variables are equiprobable. The source entropy is given by:

$H(X) = \log_2 26 = 4.7$ (bits/message).

The information content of each part design is calculated with the use of Eq. (6), where N is the number of messages of the specific design and H is the source entropy. In particular, the information content of the bottom bracket tube is

$I = 48 \times 4.7 = 225.6$ (bits)

The channel capacity, in this communication system is considered to be equal to the amount of time required by the DD to create the geometric model of each part. Therefore, the channel capacity depends on the complexity of the part geometry and is approximately equal to c = 10 bits/min.

2.2. Quantification of Information Exchange between the Process Planning Department and the Manufacturing Department.

In this communication model, the transmitted information is related to the process plans of the bicycle's parts, which are being manufactured by the company. The Variant Computer-Aided Process Planning (VCAPP) approach has been used in this application. VCAPP is implemented through the use of the Group Technology (GT)-based part coding and classification. A part classification coding system of four digits is used in this communication model [7]. It is based on both design and manufacturing attributes of the parts. Each digit can take the following values: 0, 1, 2, 3, 4, 5, 6 or 7, which depend upon the particular geometric features of the component. The number of different values each digit can take, comprise the number of variables included in the source. Thus, the source comprises k=8 digits (0,1…7), which correspond to 8 variables. The probability of each variable to be chosen is $P(X_i)=1/8$. Therefore, the source entropy is

$H(X) = \log_2 8 = 3$ bits/message.

Consider as an example, the coding process of the bottom bracket tube. The resulting code is 1200. The process plan of each part comprises four (4) variables, meaning that the number of messages generated and transmitted per part is N = 4. Therefore, the information content of the part is given by

$I = 4 * 3 = 12$ bits/part .

The channel capacity is estimated in terms of the time needed by the process planning department to create the codes of the bicycle's parts. The channel capacity is approximately equal to 2.4 bits/message.

2.3. Quantification of Information Exchange between the Manufacturing and the Assembly Department.

The manufacturing processes of the bicycle's parts, which are being manufactured in the company, are performed in this phase. The processes are defined in the process plans, which include, in detail, the required machining operations in the appropriate sequence [8]. Each machining operation is defined by a process code and a parameter, which indicate the number of preparatory operations required for the performance of the specific operation. The more complex the machining operation is, the more

preparatory operations are required. These refer for example, to the set up of the machines, the removal or inspection of the cutting tool, the definition of the cutting path and the definition of a number of parameters, which are different for each machine.

In this communication system, the transmitted information refers to the machining operations. The number of variables included in the source depends on the number of operations, which can be performed by the machine tools. Thus, k = 25 and since, these are assumed to be equiprobable, the source entropy is given by

$H(X) = \log_2 25$ bits/message or $H(X) = 4.65$ bits/message.

The number (p), attached to each variable, indicates the number of parameters needed to specify each operation. The number of messages (N), generated by each process plan depends both on the numbers of variables and of fthe attached parameters. For example, the number of messages for the bottom bracket tube, in this communication system, is N = 18 messages (Table 3). Thus, the information content is given by :

$I = N \times H = 83.7$ bits.

Table 3. Messages resulting from the process plan of the bottom bracket tube.

Part	Process Code	No. of messages	I (bits)
#1	saw01_1	2	9.3
	tapping01_4	5	23.25
	tapping01_4	5	23.25
	grinding01_2	3	13.95
	grinding01_2	3	13.95
		N=18	83.7

In this communication system each machine tool used in the manufacturing processes is considered to be a channel. Therefore, the number of channels equals the number of machine tools used in the production process. The channel capacity is different for each machine tool. For example, the capacity of the cutting machine is $C = 9.3$ (bits/min), of the tapping machine $C = 46.5$ (bits/min) and of the grinding machine $C = 27.9$ (bits/min).

2.4. Quantification of Information Exchange between the Assembly Department and the Packaging Department.

The assembly processes are performed according to the assembly plans which include all the necessary information about the type and the sequence of the assembly operations [9]. The quantification of information flow is performed with the aid of the information theory in a way which provides a measure of the degree of difficulty and of the duration of the assembly process. There are several factors, which in combination with the methods used determine the difficulty and the duration of the assembly process. Such factors for example, are the geometrical characteristics of the parts. Very

small parts in general, are difficult to be handled and therefore, difficult to be assembled, especially if the assembly process is being performed manually. The assembly process becomes more difficult when it is manual and the tolerance requirements of the part are very tight. Also, the degree of difficulty of the assembly process is affected by the position where the part will be placed (sometimes this position is difficult to be reached or another part is blocking it), and the use of auxiliary instruments during the assembly. Especially when the assembly components have tight tolerances the use of such an instrument is a great help to the assembly process.

The number of codes of the assembly processes are considered to be the variables (k) in the source, meaning that k = 6 (Table 4). The attached parameter provides information on the degree of difficulty of the assembly operations as well as on the use of auxiliary instruments. The number of variables (k) used in each process plan and that of the levels (p), attached to each variable, define the number of messages (N) that describe each process plan.

Table 4. Codes, parameters and parameters value used in coding of the assembly operations

Variable	Parameter	Param. Value	Comments
p			corresponds to the type of assembly process
hand_	h	0	component easy to be handled
		1	component moderate to be handled
		4	component difficult to be handled
app_	a	0	component at easy to approach position
		1	component at position moderate to approach
		3	component at difficult to approach position
insert_	i	0	joining with loose tolerances
		2	joining with tight tolerances and the use of auxiliary instrument
		5	joining with tight tolerances and without auxiliary instrument
scr_	s	1	screwing with auxiliary instrument
		3	manual screwing
		4	tight manual screwing
extra_	e	0	lubricating
		2	swarf removal
		5	inspection

The source entropy is

$H(X) = \log_2 6$ (bits/message) or $H = 2{,}6$ (bits/message).

Consider the assembly process of the bottom bracket tube. The messages resulting from the coding of the bottom bracket tube assembly process are N = 42 (messages) (Table 5).

Table 5. Coding of the bottom bracket tube assembly

				No. of messages	Assembly Sequence
hand_0	app_0	insert_0	extra_0	8	Insertion of the bearing in the axle
hand_0	app_0	insert_0	extra_0	8	Insertion of the bearing in the axle
hand_1	app_3	insert_0		7	Insertion of the bearing in the screw
hand_1	app_1	scr_1		6	Screwing operation
hand_0	app_1	scr_3	extra_5	13	Screwing operation
				N = 42	

Therefore, the information content is

$I = 42 \times 2.6 = 109.2$ (bits/message).

The channel capacity is considered to be equal to the amount of time required by the assembly department to perform all the necessary assembly operations. In this communication system, the channel capacity is equal to 25 bits/min. In this system, the inspection of the final assembled part is performed and it is decided whether the assembled product is the desirable one or not. The accepted parts are launched in the market.

2.5. The Definition of Noise in the Product Development.

In this section, the description of noise in the communication systems is given. The potential errors of the design drawings of the parts, are considered as noise. More specifically, the features of the parts, which are not within the specifications or can not be manufactured, are considered as noise. In this case study, three design errors have been introduced in order to compare the sequential with the concurrent approach. The error detection and recovering time, as well as the total bicycle development time for both approaches are estimated. Table 6 presents the design errors introduced in the product development phase.

Table 6. Design errors introduced in the product development

Error	Description	Detection in	No. of Affected Parts
Seat tube diameter	The frame cannot be manufactured (welding failure)	Manufacturing	5
Inclination of head tube	The offset length is out of PDS	Assembly	3
Inclination of vertical back fork	The rear wheel can not be inserted	Assembly	4

The first error is associated with the diameter of the seat tube and affects the frame, which cannot be manufactured. The seat tube is the second part that is designed and affects the designs of five parts. The error is found in that the diameter should have been larger than it is. This error is detected during the welding of the seat tube with the left and right vertical back forks. After the detection of the error, five parts must be redesigned. The second error is related with the inclination of the head tube, which is out of the specifications and is detected in the assembly process during the inspection of the assembly of the fork and the head parts. After the detection of this error, three parts must be redesigned. The third error is related with the inclination of the vertical back fork. It is assumed that this inclination is out of the specifications, and affects the insertion of the rear wheel. This error is detected during the assembly of the back wheel and four parts must be redesigned. The following section describes the estimation of the development time of the bicycle during the serial and concurrent product developments.

2.6. Total Bicycle Development Time in Serial Approach

This section describes the estimation of the bicycle development time, when the processes are performed serially. Totally, 59 parts are designed in the DD of the company. The PPD creates the process plans for 21 parts.

The first error is detected when the 10th assembly operation is being performed. The information content and time of the detection and recovering of the first error are shown in Table 7.

Table 7. Information content and time of the detection and recovering of the 1st error.

Information Content until detection(bits)	Time of Detection (min)	Information Content until Recovering (bits)	Time of Recovering (min)
Ides = 23.688	T des =2368,8	Ire-des = 2834,1	Tre-des=283,41
Iproc = 252	Tproc = 105	Ire-proc= 60	Tre-proc=25
Imnf = 1422,9	Tmnf = 1424	Ire-mnf=525,4	Tre-mnf=506
Iass=139,5	Tass = 60		
	Tdet-error1 = 3957,8		Trec-error1 =814,41

The second error becomes obvious during the assembly of the fork and the head parts. The third error appears during the assembly process of the rear wheel. The information content and the time of detection and recovering of the 2nd and 3rd error are given in Table 8.

Table 8. Information content and time of detection and recovering of the 2nd and 3rd error.

Information Content Detection (bits)	Time of Detection (min)	Information Content Recovering (bits)	Time of Recovering (min)
	Terror 1 =3957,8	Ire-des=4620,1	Tre-des=462,01
	Trec error 1 =814,41	Ire-proc=84	Tre-proc=35
Iass = 544,05	Tass = 234	Ire-mnf=976,5	Tre-mnf=980
Iass = 632,1	Tass= 25,284		
	Tdet-err2,3 = 5031,5		Trec-err2,3 = 1477,01

After recovering the 2[nd] and the 3[rd] error, a number of processes are performed in order to complete the bicycle development ($T_{bic\text{-}compl}$). Thus, the final product development time is given by:

$$T_{final}=T_{det\text{-}err2,3}+T_{rec\text{-}err2,3}+T_{bic\text{-}compl} = 6508{,}51+234{,}172= 6742{,}68 \text{ min.}$$

The above results are summarised in Table 9.

Table 9. Time of error detection, recovery and final product development in serial approach.

	Process where the error is detected	Time of detection (min)	Time of recovery (min)
Error 1	Welding of the rear vertical fork tube	Tdet-error1=3957,8	Trec-error1=814,41
Error 2	Assembly of the fork and the head parts	Tdet-error2=5031,5	Trec-error2,3=1477,01
Error 3	Assembly of the rear wheel	Tdet-error3=5031,5	Trec-error2,3=1477,01
			Tbic-compl=234,172
			Tfinal=6742,68

2.7. Total Bicycle Development Time in Concurrent Approach

This section describes the estimation of the time required for the development of the bicycle when the processes are performed concurrently. In the concurrent approach, when the drawings of one part at the design department have been completed, they are sent to the process planning department. In the mean time, the processing of the drawings of the second part is continued. In the process planning department, the process plan of the first part is being created and when it is completed it is sent to the manufacturing department. The assembly of the first part starts as soon as the necessary number of parts is manufactured. Therefore, the assembly process begins as soon as the manufacturing of the 23[rd] part has been completed. The same number of errors is considered in this approach as well as in the serial approach. The first error is detected after the manufacturing of the rear vertical fork tubes, which will be

assembled in the seat tube. This means that before the error is found, seven parts have been manufactured and 10 welds have been completed.

Therefore, the time that the first error is detected is $T_{det\text{-}error1}= 593{,}56$ *min.* After the detection of the first error, five parts must be reworked. The processes of reworking the parts are performed concurrently.

Thus, the time required for recovering the error is $T_{rec\text{-}error1}=605{,}31$ *min.* In the mean time, the design department is working on the designs of the 19th part.

The second error is detected during the assembly of the fork with the head parts that begins after the manufacturing of the head parts (subcontractors supply the head parts). Therefore, the time during which the 2nd error is detected is: $T_{det\text{-}error2}=2101{,}18$ *min*.

The design department creates the design drawings of the 43rd part, when the second error is being detected. In concurrent approach, the detection of the second and third error is not performed at the same time, since the designs of the rear wheel parts have not been completed yet. In order for the second error to be recovered, the designs of three parts must be reworked. The recovery time of the second error is estimated as: $T_{rec\text{-}error2}$=1174,04 min.

The third error is detected during the assembly of the rear wheel with the frame. The time of the detection of the third error is : $T_{det\text{-}error3}$= 3300,5 min.

The design department is working on the 40th and 41st part, when the 3rd error is detected. In order to recover the 3rd error, the design department reworks on the designs of the four parts. The recovery time of the 3rd error is $T_{rec\text{-}erro3}$=1234,67 min.

After having recovered the 3rd error, the appropriate number of processes is performed in order for the bicycle development ($T_{bic\text{-}compl}$) to be completed. Thus, the total product development time is $T_{final}= T_{det\text{-}error3}+T_{rec\text{-}error3}+T_{bic\text{-}compl}$ = 4730,632 min. The above results are summarised in Table 10.

Table 10. Time of errors detection, recovery and final product development in concurrent approach.

Error	Process where the error is detected	Time of detection min	Time of recovery min
1st : part2	Welding of the rear vertical fork tube	Tdet-erorr1=593,56	Trec-error1=605,31
2nd : part5	Assembly of the fork and the head parts	Tdet-error2=2101,18	Trec-error2=1174,04
3rd : part8,9	Assembly of the rear wheel	Tdet-error3=3300,5	Trec-error3=1234,67
			Tfinal=4730,632

2.8. Concurrent Product Development when the Information Content is less than 4.800bits.

This section describes the quantification of processes, in concurrent product development, when the amount of information exchanged among the departments is

equal or less than 4.800 bits. This means that when the messages resulting from the design department contain 4.800 bits, they are sent to the process planning department. The same assumptions of the processes and the same number of errors are considered in this case.

The amount of information resulting from the messages, which must be exchanged among the different departments, as well as the required amount of time is:

$I_{des(1\text{-}10)}$=4.671,8 (bits), $T_{des(1\text{-}10)}=467{,}18$ (min), $I_{proc(1\text{-}10)}$=120 (bits) and $T_{proc(1\text{-}10)}=40$ (min) Finally, $I_{mnf(1\text{-}10)}$ = 664,95 (bits) and $T_{mnf(1\text{-}10)} = 566$ (min) for the first 10 parts.

Thus, the first error is detected in $T_{det\text{-}error1}$=1073,18 min. In the mean time, the design department proceeds with the drawings of the parts until the information content is up to 4800 bits. Following the same procedure, we calculate the time needed to detect and correct the three errors which are equal to T_{final}=6472 min.

The previous estimations of the time required for the detection and recovery of the errors, as well as for the product development time in the serial and concurrent way are summarised in Table 11.

Table 11. Serial versus Concurrent Product Development

	Serial Approach	**Concurrent Approach**	**Time reduction (%)**
Tdet-error1 (min)	3957	593	85
Tdet-error2 (min)	5031	2101.18	58
Tdet-error3 (min)	5031	3300.5	34
Tfinal (min)	6742	4730	30

In the concurrent engineering approach, several channels can be used, in parallel, for transferring the information among the various departments. Also, the amount of information transferred through the channels is reduced, the errors can be detected at earlier stages of the processes, and a lot of reworking can be avoided. In the case study, the final product development when the processes are performed concurrently is reduced by 30%, compared with the serial approach. The time of the first error detection is reduced by 85%, while the time of the second and third error detection is reduced by 58% and 34% respectively. Although the 2nd and the 3rd error are not simultaneously detected, the detection time compared with the one in the serial approach is still reduced. Figures 4 and 5 present the development time in serial and concurrent product development.

In the approach of concurrent product development, with the constraint that the information transmitted should be equal or less than 4800 bits, we note that the time reduction is only 3%. This should not be discouraging because the percentage of reduction depends on several factors, such as the product structure, the processes, and the constraints themselves for the amount of information transmission.

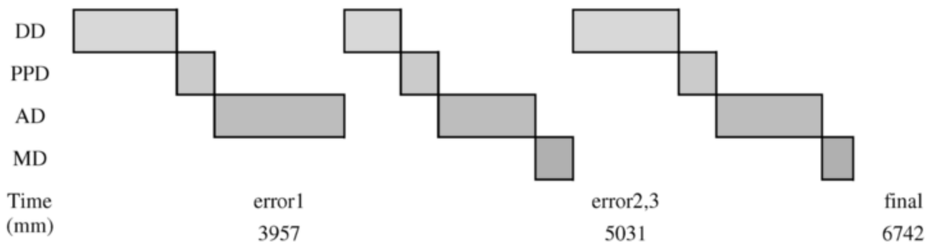

Figure 4. Development time in serial product development

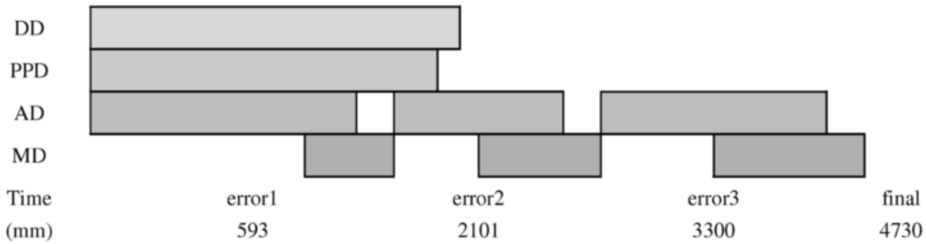

Figure 5. Development time in concurrent product development

3. Conclusions

The implementation of CE approaches help manufacturing companies to retain and increase their market share. Moreover, CE approaches provide the means of reducing the product development time and the manufacturing costs, while increasing product quality [10, 11]. There have been developed various methodologies to support CE activities. However, they do not provide adequate information about the quantification of the transferred messages among the departments of the company.

This paper describes the development and implementation of a methodology based on Information Theory (IT). This methodology provides a quantitative understanding of the information exchange, necessary for the design and manufacturing planning of products. Furthermore, the basic terms used in IT, namely information content, source entropy, channel capacity and time of transmission are defined in this paper and the developed model is described, which helps in optimising the product development cycle.

The case study is the implementation of the developed model in a bicycle manufacturing company. The model developed, is used for quantifying the information exchange among five departments of the company, namely those of design, process planning, manufacturing, assembly and packaging. The total bicycle development time is estimated both by the serial and concurrent approach. Three errors in the designs of the parts are introduced in order for the development time between the two approaches to be compared. The results show that the errors have been detected and recovered earlier in the concurrent approach, thus leading to shorter total bicycle development time.

However, the implementation of IT to the manufacturing processes is not a common and easy procedure. The engineers must face several difficulties related to the definition of messages, symbols, coding and decoding processes. Messages in the source, should be defined in such a way so as for the minimum information content to be transferred among the departments.

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Cost Engineering in CE

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A proposed method for cost estimating for low volume infrequent electronic products

Newnes, L.B. and Mileham A.R.
Department of Mechanical Engineering, University of Bath, Claverton Down, Bath, BA2 7AY, UK. L.B.Newnes@bath.ac.uk

Abstract. This paper describes current research in the area of low volume product cost estimating. It examines current cost estimating practices and the problems using these for low volume, infrequent products, such as complex electronic systems. The traditional approaches are described in detail and how the cost estimating relationships are ascertained. The approaches used within sectors such as aerospace, construction and injection moulding are discussed and evaluated. Using the findings from the traditional approaches a proposed method for low volume products is introduced. The paper describes research that has started within this area with a number of partners. The hypothesis are presented which will be evaluated over the next period of research through industrial case studies.

Keywords: cost estimating, low volume products, electronic products.

1. Introduction

Cost estimating of products is critical in today's environment. Many products and buildings run over budget. This has led to the cost estimating process being a high profile topic, especially in projects that involve public money. Examples of such overspends include the construction of the Scottish Parliament, where the predicted cost was £40Million. It increased ten fold to £431Million. (Cochrane, 2006). Within construction it is not unusual for the costs of a project to soar especially with the current tendering process where suppliers are tied down on costs to 98% (Newnes, 2005). With this, one way that the suppliers of the service make their profit is through design changes. Naturally this does not only occur in the construction sector, large engineering projects with long lead times normally involve such design changes. Again these design changes are how the suppliers can enhance their profit and is evident in other sectors such as defence. Here spending is under close scrutiny and cost estimating is becoming more critical as the cost per unit increases and budgets decrease (Vollerthun, 1998). From the worst case scenarios and the need to provide good through-life-costing there is a demand for improved cost estimating processes. Where a traditional manufacturing process is being used and a frequent product or a product family is being costed the accuracy of the estimates is relatively high. Where the issues arise is when the product is new, there are no similar products / processes in place or where the development from concept to final product can be in tens of years. In this area the issue of cost estimating is extremely difficult as it is the best 'guestimate' that is used.

This demand for reliable cost estimating is illustrated within industrial sectors where there is a range of capabilities in cost estimating with some companies developing in-house spread sheets whilst others rely on tight control or cost management, during the build phase of the product. Despite these challenges customers are demanding quite precise estimates of acquisition, maintenance, upgrading, refurbishment and disposal through the products lifecycle. This creates difficulty in the transfer from the design requirement of a product to the specification and then to the final build and in-use/disposal phases. Designers of a product are mainly concerned with functionality, aesthetics, costs, quality and manufacturability. In the early stages of the design process the designer focuses on achieving the specification, in general the functional specification of the product. Although this is deemed the norm, problems arise in this phase especially as much of the literature indicates that 50-70% of the avoidable costs of a product are in-built within the concept design stage (Clarke & Lorenzoni 1979). This is also the point in the process where there is very little concrete information. For example in an aircraft design you may have the capacity (passengers, equipment etc), the distance it needs to travel between fuel changes and overall work envelope for the aircraft specified at the concept stage. In this type of product design the accuracy of a cost estimate improves with the volume of information available (Corbett 1986) and as only basic information is available at the conceptual design stage, cost estimating tends to be inaccurate and of low priority.

As the design details are expanded and the final product is selected this building in of the avoidable costs can lead to a product that is over budget and also difficult to then re-assess or abandon because of its engineering inertia. At this stage many companies then attempt to save costs on the final manufacturing processes or materials. This requires all the effort for cost savings being concentrated towards reducing the cost of 30% of the product which is restrictive. The likely consequence of this policy is typically a reduction in both cost and quality.

Due to this conflicting nature of the design process and cost estimating there has been a drive towards providing methodologies and approaches that can assist in the cost estimating process. There is also a plethora of commercial systems and consultants that promise their tools/approaches can solve the cost estimators' dilemma. The next sections in this paper describe some of the current approaches and lays out a path for the future research activities of the authors in the area of low volume cost estimating.

2. Current Approaches to cost-estimating

There are a number of approaches that can be used in cost estimating. Two of the basic techniques are generative cost estimating and parametric cost estimating. The techniques have advantages and disadvantages. The use of the generative process builds upon the data being gathered and as the design increases in detail the costing is then generated. It is generated using specific details such as material costs, processing times and so on. It has the advantage that you calculate the cost per product but the disadvantage that there is a need for a greater level of detail than is normally available. This detail is only available once the product is well past the basic concept stage and by then as described earlier the avoidable costs are already built in. The other approach is that of using parametrics. Here the estimate is achieved based on past experience, using findings from past products and

estimating the expected cost. Naturally this is advantageous when there is a relationship to cost that is evident from previous products. It is not very good when it is a one-off product or when it is so novel in terms of design and material/processing that it is not possible to generate parametrics conventionally and the only course of action is to use the generative approach.

There has also been much research into the methodology to be used for early cost estimating. Chin and Wong (1996) describe a Knowledge-Based cost estimating approach that was used in a domestic appliance company to assist mould cost estimation at the concept design stage that used a decision table approach. Decision tables were also used by Qiang (1991) in a package that advised on polymer material selection and Design for Manufacture (DFM) in mould design. Several researchers (Shirly 2001, Musilek 2000, Jahan-Shahi (1999) have used a Fuzzy Logic approach for cost estimating with good effect. Feature based cost estimating systems for castings have been developed by both Poli (1990) and Bidanda (1998) the latter incorporating a high level of intelligence. Researchers have also used a Neural Networks approach to provide a self-learning environment for cost estimating (Zhang & Fuh 1998). Others have taken an Expert Systems approach for early stage cost estimating, for example Nagarajan (1996).

Researchers in the cost estimating domain have also focussed their efforts in the concept design phase. Examples of costing research focussing on this particular topic include work by Curran (2002, 2005), where the use of cost modelling within the conceptual phase of aerospace uses categorisation methods such as manufacturing processes, weight of material and volume. This focuses on traditional techniques used within the aerospace sector and uses the cost estimating relationships (CERs) for the industry, in particular weight and material. The use of weight, manufacturing processes and materials are also used by Mileham et al (2005), Currie (1996) and Nasab (2002).

The use of key attributes is one area that is relevant across many sectors and cost prediction where these can be validated using historical and current product information. There has also been much research into the issue of top-down (Pugh, 1992, 2004) approaches to cost modelling versus bottom-up approaches. Work by Roy (2001) also illustrates that the use of Cost Estimating Relationships (CER) should also focus on design time/thinking time as well as the geometry and specific CERs of the product and uses qualitative and quantitative costing in areas such as software.

An example of a typical CER is illustrated in Figure 1, where for an injection moulding product one can see the cost increase with the material weight, hence the CER in this particular case can use weight as one of the methods to gain a cost estimate for a product. Naturally for the real cost estimate other factors such as complexity, surface finish, accuracy etc are all built in to the final cost estimate.

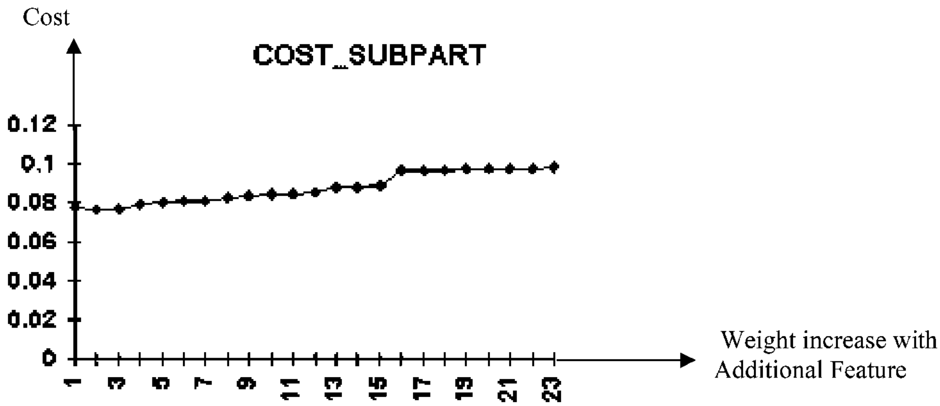

Figure 1. Cost of sub-part against the cumulative weight of a product

3. Commercial Cost estimating Systems

In line with this demand there is a range of commercial packages on the market including SEER-DFM, from Galorath, and PRICE-H. These provide useful tools for cost estimating and use historical data to assist in the decision making process. In particular they provide accurate costing data for frequent/similar products at the detailed design level. They include the hardware costs but provide little detail on the non-recurring costs and through-life-costs. In general these tools are effective for repeated products that build on a base product model with incremental design changes where much of the detail is available. Although they still offer advantages, for this particular research there is a need to establish a set of rules and requirements to fully understand the complexity involved with such products in terms of unit production costs, through-life-costs and non-recurring costs and how these can be represented in such a way that the rules could be incorporated within a suitable environment. In particular an environment that enables the designer to use cost as one of the design criteria in parallel with functionality and aesthetics.

4. Low Volume – Long Life Products and Cost estimating

Currently within the industrial sector there is a range of capabilities in cost estimating with many companies adopting the use of spread-sheets. Although there is a mixed approach at a macro level there is very little or no integration and feedback using these throughout the supply chain. Within the extended supply chain that operates within the electronics sector the need to work with key suppliers at the concept stage and have subsystem integration/feedback to/from suppliers is paramount. There is a need to provide innovative methods where this feedback in terms of cost can be achieved. One of the challenges for this research is the ability to model costs at various stages within the product design cycle from the early concept stage to the detailed design and maintenace/life of the product that both the customers and suppliers can share trade information without compromising IP. Standard approaches are also of interest for cost modelling (ISO, 2003).

Both the AeIGT (2004) and the EIGT (2005) recognise the need and importance of cost estimating throughout the extended supply chain. This becomes particularly important in the area of global working where many companies tend to focus on collaborative concurrent teams that are product specific as well as some of their products being designed by suppliers (in defence this can be 70%, (Hayward, 2001)). Concurrent engineering reduces lead-time by carrying out manufacturing systems and tooling design in parallel with product design and for this to be effective it is necessary to design the product "Right-First-Time" in all aspects including costs. Also in this environment there is a growing need to provide designers with simple, accurate methods of estimating costs at the concept stage for both the product and the non-recurrent costs through the life of the product. One of the problems with concurrent product development is that the teams are dispersed after the product has been developed and manufactured. This increases the difficulty in keeping the knowledge together for use within other teams and key partner suppliers at a later stage (Terwiessch, 1999).

The aim of the research proposed in this paper is by using the knowledge of parametric and generative cost estimating techniques, determining how the cost estimate be found for low volume products in particular electronic products within the defence sector. This proposed research focuses on defining a methodology for costing products of this nature by creating parametric cost prediction models at sub-system level rather than the whole system level. Achieving this goal will assist UK manufacturers of electronic products to compete in the world market. The combined features of varying customer requirements, multiple sub-systems, highly complex and long lifecycle products means that conventional parametric approaches are impractical and highly unreliable for estimating lifecycle costs.

Previous research by Hadfield (1974) proposed that the CERs for subsystems were only available once the conceptual design had been presented in greater detail. The cost estimates were then evaluated for subsystems and they were re-designed if the cost was too high. He argues that this is ineffective and that the most appropriate approach was the proposal of top-level whole system CERs using for example the satellite payload as a relationship for calculating the cost. However, current research includes that of Purvis et al (1997) who presented work on the cost of satellite sensors and payloads in space. As expected they described that many cost estimating systems use historical data which is not appropriate for the future space systems due to the advancement in technology and materials. Their view was to focus on a road map, a process to follow in particular enable the cost estimates to be achieved at various levels as appropriate with the models being selected based on the complexity required rather than the complexity which in the past had been the one that was easiest to apply with the given data. This approach should also be applicable to low volume products in the defence sector where one of the key research aims is to identify where the appropriate level of complexity is and when/where CERs or generative approaches should be applied.

The approach of defining where an overall estimate is appropriate and when to undertake sub-system estimates is one that is being applied in this research. In determining when a sub-system cost estimate is applicable the project will exploit the fact that many complex low volume products are invariably modular in design and

production, are typically owned by a functional department and their costs can be estimated with greater precision The deliverables from this research will be guidelines for a new approach to parametric cost prediction that is built upon identifying appropriate sub-system levels and defining the decision rules that will enable industrialists to position their effort on key elements within these sub-systems. This will be achieved by classifying the methods and techniques and evaluating the rules for estimating cost information from the concept design phase through to actual cost of the designs. From this, an overall cost prediction methodology that can be used from the early concept stage cost estimation through to 'real costing information' will be created. This methodology will focus on through life information, i.e. integrated costing approaches from the initial concept design stage to the in-use/re-use stages. This is particularly pertinent in the drive toward a service economy which many sectors face today.

The proposed approach is shown in Figure 2. In this the data is transferred under the Design for 'X' approach where an iterative process provides the information which determines whether the use of overall CERs should be applied and rules are used to ascertain when a sub-system level of detail/CER should be applied. The rules involve attributes such as complexity, modular score (i.e. is it similar to another subsystem), innovation, new processes and a historical value.

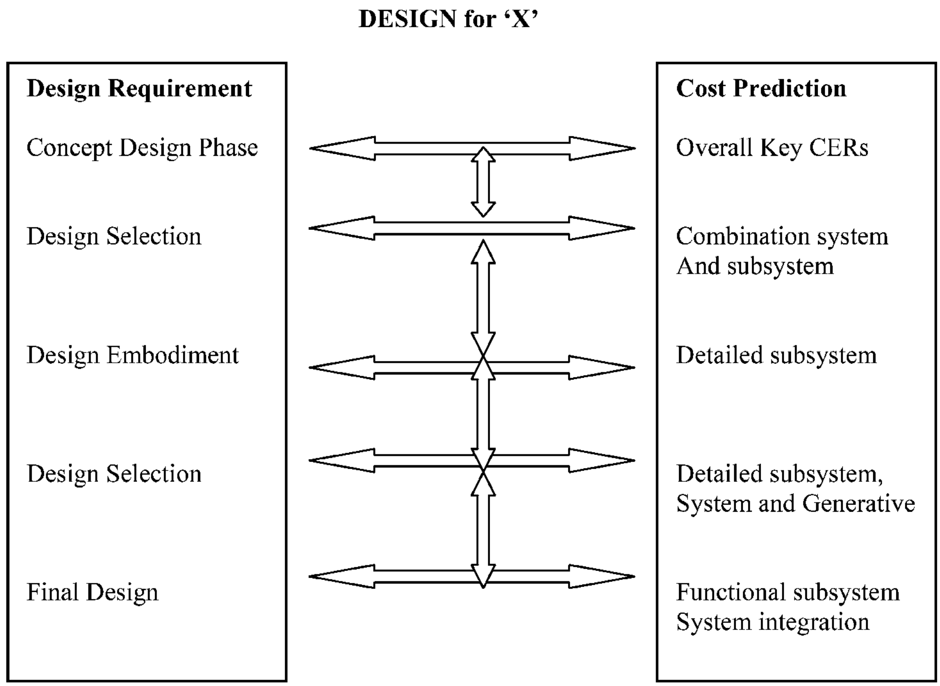

Figure 2. Design for Cost and selection of appropriate CER approach Conclusions

Conclusions

The outputs from this research aim to provide an integrated methodology for cost predictions throughout the supply chain. The methodology, rules and techniques to enable such product cost estimating to be practicable and applicable will be provided. The aim is to use this methodology to enable cross-functional teams to access approaches used for sub-systems costing so that they can draw on expertise that is functional in nature. The methodology and rules will provide guidance to users on when it is appropriate to undertake whole product/system estimates and when it is appropriate to perform sub-system analysis of costs. This will depend on the types of products and whether the sub-system design can use the modular aspect of the product and use similar sub-systems to assist in the estimating phase. This is of particular importance for low volume electronic products within the defence sector.

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Understanding Decision Making in Cost Engineering Using Protocol Analysis

Oliver HOUSEMAN[1] and Rajkumar ROY
Manufacturing Department, Cranfield University, Cranfield, United Kingdom

Abstract. Previous theories describing the cost engineering process have been derived from prescriptive or descriptive analysis but there has been no empirical test of these theories. The protocol analysis techniques utilised in this study provide a method to inspect the cost engineering process at a cognitive level. A hypothesis describing the thinking process of a cost engineer is objectively tested using the results obtained from protocol analyses of cost engineers engaged in a detailed cost estimate. The hypothesis is objectively supported for the first time by these findings.

Keywords. Cost Engineering Process, Cost Estimation, Protocol Analysis.

Introduction

Past research within the field of cost engineering has primarily focused on the development of computer-based models that rely on subjective evidence of the costing process. In the 1950's researchers and practitioners began by applying engineering principles to develop cost models in an effort to improve estimating consistency and speed [1]. Today there are several types of cost models: parametric-based, analogy-based, and detailed-based (bottom-up). Different tools and applications have been developed in order to help give quantitative results for a cost estimate. However, there remains a difficulty for managers to fully understand a final estimate, if they are unable to comprehend the rationale and assumptions underlying an estimate [2].

This study concentrates on how cost engineers actually think during an estimate. By looking at a cognitive level, the aim is to understand how cost engineers think when making decisions and so address the issues of how they rationalise and make assumptions. The research uses techniques developed in psychology and behavioural science that allow objective studies of the costing process to be undertaken by. One technique of data collection that is believed to be particularly effective when studying cost engineers is protocol analysis [3]. This technique has previously been developed and successfully implemented in the study of designers [4]. Protocol analysis requires asking a cost engineer to think aloud whilst performing an estimate and his or her actions and verbalizations are recorded. This allows observation of the cost estimating process in detail and the cognitive actions of the cost engineer.

[1] Corresponding Author: Oliver Houseman, Decision Engineering Centre, Cranfield University, Cranfield, MK43 0AL, United Kingdom; E-mail: o.houseman@cranfield.ac.uk.

Cost Engineering/Cost Estimating

The detailed cost estimating method, also known as bottom-up or grass roots, is distinguishable from other costing methods as it demands access to detailed product data, and accurate allocation of key cost elements such as, labour, materials and production techniques. It is this method of estimating that has been analysed in this study. However, protocol analysis could easily be used to analyse the other methods of estimating. Detailed cost estimating commences when a detailed description of the final component is available. The process may also include periods of analogy-based cost estimating that are required to elaborate or rationalise a decision that has been based on a previous experience.

Hypothesis

Protocol analysis is used to test a hypothesis about the cost engineering thinking process. The hypothesis is;

1. In the process of estimating the cost engineer cycles between three cognitive activities of analysing the problem, proposing a solution or synthesising and evaluating a proposed solution.

1. Protocol Analysis

The work described in this paper builds on work undertaken in previous studies by the authors. Five protocol studies of engineers engaged in detailed cost estimating were used as a vehicle for the development of the described analysis method used here. Details of the study appear in [5].

Two important factors are taken into consideration when analysing the protocol data. The coding scheme used must adequately reflect the complexity of the data without distorting it, and the process of coding the protocol must be as objective as possible. The first of these considerations can be addressed by a combination of coding categories that are derived from real data collected and categories that are derived from theories of costing. The second consideration can be addressed by the use of two coders and a consensus approach to the final coding result. Whilst there have been criticisms of the use of the think aloud protocol analysis as a means of producing a unitary cognitive model [6], the current approach offers the opportunity to gain some insight into the range of cognitive activity in the cost estimating process without claiming complete insight. As such this study provides useful support for the development of cognitively-based models of cost engineering.

1.1. Coding Scheme

The coding scheme makes use of multiple dimensions by using up to four codes to capture the aspects of each segment coded. Two dimensions are concerned with the cost engineer's navigation within the **'problem domain'** and two dimensions are concerned with the **'strategies'** used by the cost engineer. The cost engineer's interaction with the estimating problem can be characterised by navigation through a two dimensional space representing the **'problem domain'**. One dimension is the '*level of abstraction*' and the other is concerned with the specific '*problem area*' being addressed. The cost engineer can be considering the problem at a '*level of abstraction*' that ranges from a high level to a detailed level. Between these two extremes an arbitrary number of levels may be identified. When deciding on the number of levels to be used in the protocol analysis, it is necessary to consider the coding process. More than four levels are difficult to categorise consistently and less than three levels does not capture all of the detail in the protocols. The problem used in this study could be readily categorised into one of four levels. [7] presents the full coding scheme in detail including the four codes used to capture the '*level of abstraction*'. The paper also describes the second dimension of the **'problem domain'.** This is captured by one of five codes indicating when the subject is reasoning about either the '*materials'*, '*production processes'*, '*overheads'*, '*costs'* or the component '*parts*'.

The cost engineer's **'strategies'** when undertaking an estimating task can be viewed in two ways. The overall approach to the problem is captured in the '*macro strategy*' coding scheme. Whilst the engineer's immediate actions can be identified and classified into one of a small number of categories, recorded in the '*micro strategy*' dimension. The purpose of coding the *'macro strategy'* is to capture the subject's long term process in terms of their approach to the overall problem. Each subject's approach can be different and so it is difficult to describe the subjects' **'strategies'** using a small number of fixed categories. The *'macro strategy'* coding consists of dividing the protocol into a small number of large segments which are numbered. Each segment represents a different activity. A number may appear more than once in the protocol as it is possible for a cost engineer to return to an activity. The *'micro strategy'* coding scheme has a large number of categories that were developed from real estimating sessions [8] and these categories are collected in groups. There are four groups used in the coding of the subjects' *'micro strategy'*: *'analysis of the problem'*; *'synthesis of a solution'*; *'evaluation of a solution'*; and *'other activities'*.

2. The Experiment

This study has involved eleven cost engineers from various industries. They were employees of Rolls Royce, the European Space Agency and the Ford Motor Company as well as independent cost consultants, providing a valid sample from the aeronautical, aerospace and automotive industries. At the beginning of the experiment the purpose of the research, the intended process and the steps taken to protect the collected data were described to each participant. It was also necessary to emphasise the aim of capturing only the participant's cognitive actions during the estimate and not emotions or hidden thoughts that were irrelevant to undertaking the task.

The task the participants carried out was a detailed cost estimate of a standard mountain bike using only a pen, paper and calculator for approximately one hour. The bike was chosen for the following reasons:

- It was a universally familiar object.
- It contained many different parts, processes and materials and so each participant should be capable of assessing competently at least a few of the parts.
- It is lightweight and therefore easily transportable if required.
- It cost a realistic price and was therefore not too ambiguous/complex to estimate.
- By using the same item for each subject direct comparisons could be made.

It is noted that the subjects do not normally estimate the cost of a mountain bike or undertake an estimate without the support of a computer based tool and that this lack of domain knowledge and change of estimating method may influence the results.

3. Results from the Protocol Analysis

3.1. Protocol Data

A set of graphs were produced to represent a summary of each estimating protocol with the four coding dimensions recorded together. Figure 1 shows the typical result. The lowest section of the graph shows the results for the levels of abstraction dimension. Above this section is the problem area dimension. The *'micro strategy'* dimension appears in the third section from the bottom. The uppermost section of the graph shows the *'macro strategy'* dimension. The trace starts at the lowest level, corresponding to the first *'macro strategy'* activity and shows the subject's progress through to the final activity. Each activity has a unique code which is recorded in the transcript of each participant's session.

All subjects move rapidly backward and forward between categories in the first three dimensions while following a more direct and slowly changing path in the *'macro strategy'* dimension. They all begin with a *'micro strategy'* in the *'analysis'* group and all move quickly to *'synthesis of the problem'*. All subjects begin at a high *'level of abstraction'* and all except one began by considering the *'parts'*. The end point of the estimating episodes are more varied but there is a tendency towards ending the session considering the costs at an intermediate *'level of abstraction'*, while considering the *'production process'*. Most subjects end the episode in the evaluating group of the *'micro strategy'* dimension.

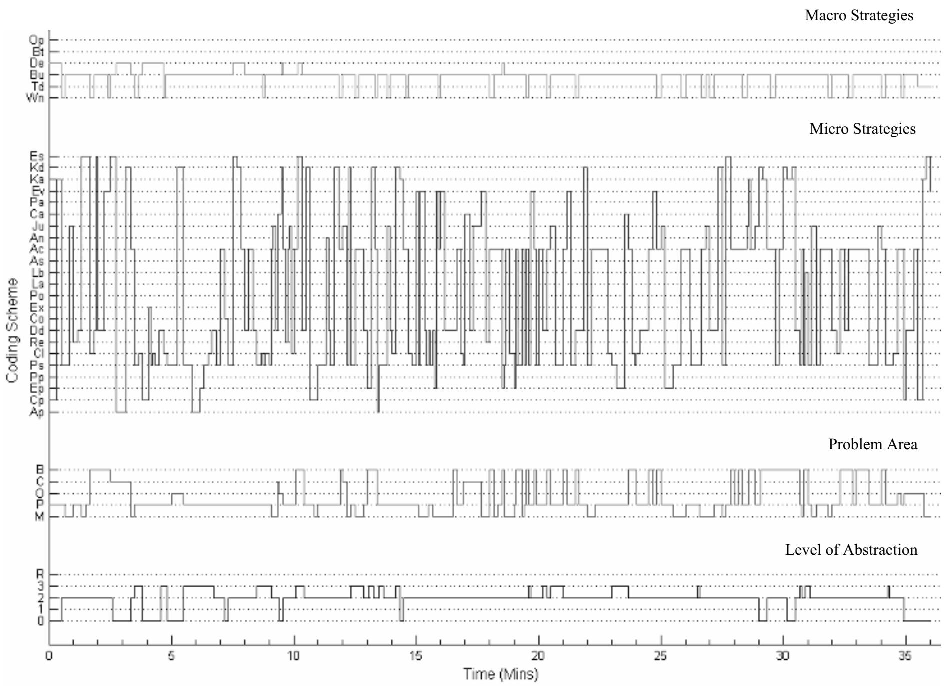

Figure 1. Typical activity during an estimating episode.

4. Tests of the Hypothesis

4.1. Analysis, Synthesis and Evaluation

The hypothesis can be tested using the *'micro strategy'* data that has been collected. The hypothesis states that the cost engineer cycles between the three activities in the order of analysis of the problem, synthesis of a solution, and then evaluation of the solution.

Both graphical and statistical approaches are used to test the hypothesis. A set of graphs illustrate the *'micro strategy'* dimension by filtering the data using a moving weighted average filter. The weighted average filter used in this analysis is derived from a normal distribution with a standard deviation of 15% of the total time. The three categories are plotted together. Figure 2 shows the general trend where subjects begin by analysing the problem for a short period of time. Their time is then divided between synthesis and evaluation. The graphs generally support the hypothesis. There is a general trend in the graphs for more time to be spent on analysis at the beginning of the estimating episodes with time being spent mainly on synthesis and evaluation later in the estimating episode. Although the example given in Figure 2 shows a trend towards more evaluation at the end of the estimating episode the trend is less apparent in the graphs for other estimating episodes.

The graphical results generally show that there are fewer analysis events later in the estimating episodes and that after initial analysis is complete, the cycle tends towards a two state cycle between synthesis and evaluation. To support this graphical interpretation of the results the centre of gravities of the data were used.

The centre of gravity is the balancing point at which the subject has spent as much time considering a category so far in the estimating episode as they will spend in the rest of the episode. The centres of gravity are expressed as percentages of the total episode time. This allows episodes of differing lengths to be compared.

The hypothesis predicts that the centres of gravity for analysis are significantly before fifty per cent of episode time, the centres of gravity for synthesis are not significantly different to fifty per cent of episode time and that the centres of gravity of evaluation are significantly after fifty per cent of episode time. The results in Table 1 show that the centres of gravity for analysis are significantly before fifty per cent of the episode time, the centres of gravity for synthesis are not significantly different to fifty per cent of the episode time and the centres of gravity for evaluation are reasonably later than fifty per cent of the episode time.

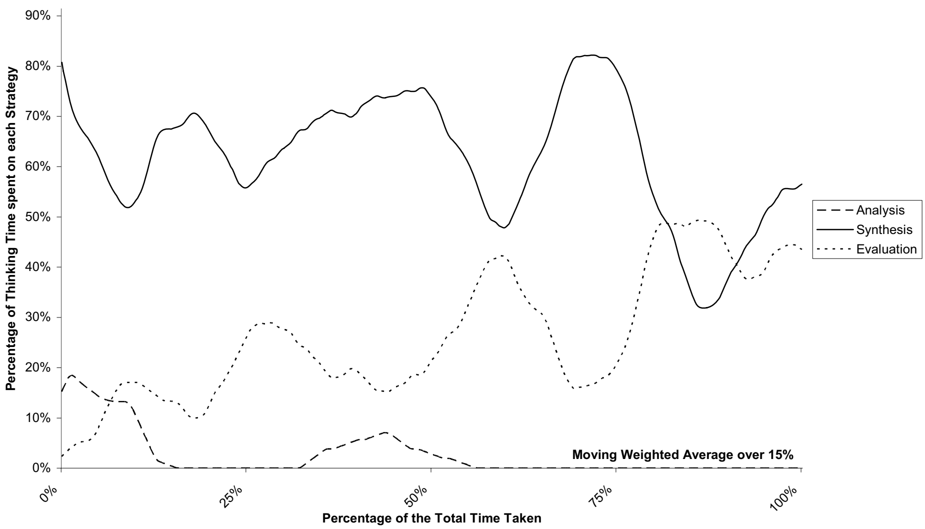

Figure 2. A typical graph for Micro Strategy Groups verses time.

Table 1. Comparing the Centres of Gravity for Analysis, Synthesis and Evaluation

	Analysis	Synthesis	Evaluation
Average Location of the Centre of Gravity as a Percentage of the Total Time Taken	29.54%	50.93%	56.49%

5. Conclusion

Protocol analysis is used to capture and represent the cost estimating process as a sequence of events in time. Protocol analysis techniques have been extended through the use of a domain dependent coding scheme based on generic models of estimating and was validated by two independent experts. These techniques allow us to bring quantitative structure to the qualitative data that is collected during a cost estimate, facilitating the articulation of many aspects of the behaviour of cost engineers. A hypothesis that describes the thinking process of cost engineers was proposed and objectively tested. Support for the hypothesis has been found.

An expert cost engineer generally begins a cost estimating session by analysing the problem of estimating the product. As the session progresses the cost engineer focuses mostly on the synthesis of the problem by proposing many different ideas for a range of problems relating to the product. A cost engineer clearly engages in a decision cycle of analysis, synthesis and evaluation. Towards the end of an estimate the cost engineer's activity is focussed on evaluating the low level decisions at a higher product level.

As research in cost engineering moves from simply making observations to a stage of making generalizations from the observations and onto building models, it should be possible to establish the principles of "good estimating". The principles could be both taught and applied whilst attempting to also establish objective criteria for the assessment of estimating ability. This study represents a beginning/observational part of this research. Future progress will take place in three areas: further measurements can be derived from the data; assessment of other hypothesis about estimating can be tested; and the technique of protocol analysis and the coding scheme can be further developed.

The protocol data collected for this study represents a rich source which may be used to test further theories about the estimating process. Future research will include analysing the amount of time spent on a particular activity over the duration of the estimate and the sequences of transitions between activities. Another aspect that may be investigated is the length of time spent in a single segment of activity before moving on. A spectrum of segment times could be constructed and the average segment time for each activity could be compared. It would then be possible to address questions such as whether a cost engineer spends longer in segments of analysis than in synthesis or evaluation. This research will be presented in future publications by these authors.

In addition to examining the data to gain insights into the cost estimating process, further hypothesis derived from current views of the cost estimating process may be tested using the data. The hypothesis tested in this work is preliminary and general in nature. Hypothesis more specific than that presented can be tested. Some questions that could be addressed are: do cost engineers in all disciplines follow a top down or bottoms-up approach; do cost engineers in some disciplines spend more time on analysing the problem; do cost engineers in some disciplines spend more time reasoning with parts instead of production process; is there a difference in the activities of novice versus expert cost engineers?

The method used in this study may be further developed to address specific questions about cost engineering. The authors are currently investigating ways to extend the method to examine how differences found between novices and experts can improve training methods.

Acknowledgments

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Producibility Awareness as a Base for Design Automation Development – Analysis and Synthesis Approach to Cost Estimation

Fredrik ELGH[1] and Mikael CEDERFELDT
School of Engineering, Jönköping University, Jönköping, Sweden

Abstract. The demand on the level of reliability and accuracy of cost estimation increases in a competitive environment and as the products are getting more and more optimised. When different courses of action are to be evaluated small changes in customer requirements, design features and parameters, and production properties has to be handled with caution. Small changes can imply: low level of conformability with the production system, highly increased cost, and extended manufacturing lead-time. It is of paramount importance for the product success and the company's profit that a system for automated cost estimation is sensitive and can reflect these effects. Design automation system incorporating producibility and cost estimations support either analysis driven or synthesis driven producibility estimation, or both. The later is an approach that allows for decreased recourse and time demand as the system only generates design proposals which the company can produce with its manufacturing resources. This work presents some of the views on which a design automation incorporating producibility and cost estimations should by developed. It also presents the concepts of analysis driven and synthesis driven producibility estimation and gives some examples of there use.

Keywords. Cost Estimation, Design Automation Development, Producibility Evaluation, Variant Design

Introduction

With the steady growth of a global market that now affects all businesses, and where companies mainly compete through the use of product sales prices, every step towards saving time and money in product development and production preparation, as well as in manufacturing, is of paramount importance. [1] refers to the "Three Cs" model (Fig. 1) in explaining the difference between cost advantage and value advantage. The cost value of a product is determined by the cost differential between a company and its competitor, based on manufacturing costs and (often) company size and sales.

[1] Corresponding Author: Fredrik Elgh, School of Engineering, Jönköping University, P.O.Box 1026, SE-551 11 Jönköping, Sweden; E-mail: fredrik.elgh@ing.hj.se.

Value advantage, on the other hand, is based on how the customer perceives the product and how well it fulfils the customer's requirements. Companies can compete in this area by providing high quality, customer-tailored products, with short lead times, and competitive prices. Because of this, there is a need to target lower costs and add product value by focusing on manufacturing and production preparation as well as product development.

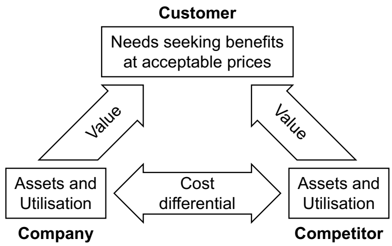

Figure 1. Company, its customer and its competitors, the "Three Cs" [2].

Much research concerning cost estimation in product development focuses on the early phases [3, 4 and 5], where the problem is lack of information about product and production properties. For many companies with mature products and automated production, the lack of detailed information is not the main issue. What they need are methods and tools for fast cost estimates with high precision, little manual effort, and low cost.

One such tool is design automation which can be a powerful tool in the continuous endeavour to cut lead times, workloads, and, ultimately, costs in order to become more competitive. Also, cost estimations incorporated into design automation can lead to enhanced producibility. The demand on the level of reliability and accuracy of cost estimation increases in a competitive environment and as the products are getting more and more optimised. When different courses of action are to be evaluated small changes in customer requirements, design features and parameters, and production properties has to be handled with caution. Small changes can imply: low level of conformability with the production system, highly increased cost, and extended manufacturing leadtime. It is of paramount importance for the product success and the company's profit that a system for automated cost estimation is sensitive and can reflect these effects.

There are three approaches to incorporating cost estimations in an automated (or computer supported) design process and thus enhancing producibility: analysis driven producibility estimations; synthesis driven producibility estimations; and a combination of the two. These approaches will be further discussed throughout this paper.

1. Why Cost Estimation in Design?

The estimation of product cost has been pointed out as a central nontrivial activity in the design process by a number of authors:

"*One of the most difficult and yet important task for a design engineer in developing a new product is estimating its production cost.*" – [6]

"*Rapid cost-estimating systems are necessary to enable design teams to take good, sound decisions early in a design task...*" – [7]

"... cost is an extremely important factor in choosing a concept, because it is one of the factors determining the economic success of the product." – [8]

"*It is important to identify cost factors as early and as accurately as possible in the design process.*" – [9]

"...it is not always easy for a company to determine the exact costs of components used in products." – [10]

"*What is needed are reliable techniques for costing much earlier on in the design process, and these are not yet widely available.*" – [11]

According to [11], cost is one of the most fundamental criteria for the evaluation of design proposals. This is probably the main cause for cost estimation in engineering design. But there are other purposes, such as [12]: evaluation of the market opportunity of a new product concept, identification of cost drivers with a subsequent analysis of their added value to the product, and improving the designers' awareness and knowledge of how the product cost is affected by their decisions. On a company level, the continuously increasing focus on cost can be seen as result from a shift from a local to a global market and a change in the shareholders view on ownership. This can be illustrated as follows:

- In a market with no competitors the price is set by the company, i.e. Cost + Profit = Price
- In a market economy with well established competition the price is set by the market and the profit depends on the company's cost, i.e. Price – Cost = Profit
- A market economy combined with a focus to satisfy the shareholders demand on return on investment results in a focus on cost as a constraint i.e. Price – Profit = Cost

Design to cost is based on that a substantial portion of the product's cost is committed during the design phase as a result from the decisions regarding its design. The objective is to make the design converge to an acceptable cost and achieve an affordable product. A cost goal is set based on the price the customers are willing to pay and the level on return on investment demanded by the shareholders. The cost goal is allocated to the elements of the product and the designer must generate solutions within this constraint. To achieve this designers need a tool to determine the impact of their decisions. According to [13], a tool that can be used to predict and estimate the cost with acceptable accuracy requires different types of input as depicted in Figure 2.

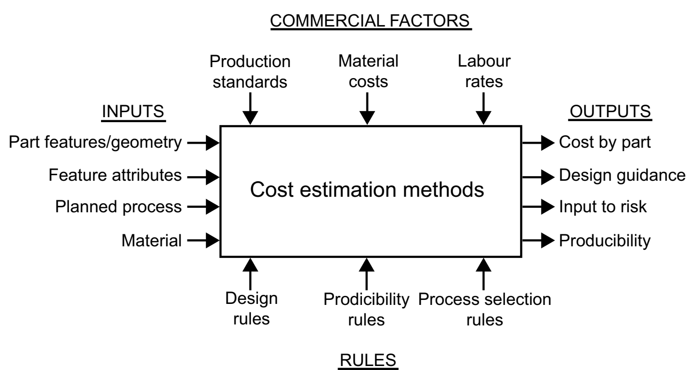

Figure 2. A design to cost model [13].

2. Producibility Awareness

It is a fact that the decisions made early in the product development process have significant impact on producibility, quality, cost, time-to-market and thus the ultimate success of the product in the market place. All the information related to a product's life cycle should be used to enhance the knowledge in the upstream phases allowing for proper decisions to be made. This is achieved with paralleling the different tasks and the support of information exchange. Concurrent engineering (CE) has been recognised as a philosophy tearing down the walls between organisational functions (e.g. marketing, product design and manufacturing) within the traditional sequential product development process. The approach is not entirely novel but the constantly increasing need of company improvements calls for new methods and tools to be developed in this area.

Design for X-abilities (DFX, such as design for manufacturability, affordability, maintainability) is a set of metrics that can be used as measures focusing on different lifecycle functions. According to [14] most DFX metrics are based on heuristics or some type of scoring method. To fully adopt a concurrent engineering approach requires that all lifecycle issues are considered in the design stage. Besides the use of different metrics a proactive approach is necessary.

2.1. Design for Manufacturability

Design for manufacturability is an approach to design that, according to [15], "…fosters simultaneous involvement of product design and process design" and is performed in the design phase of a product. This implies a flexible manufacturing system, comprising a number of different manufacturing processes that can be adapted or even changed. Many of the DFM/DFA guidelines and metrics are applicable for a specific average type of manufacturing processes, e.g. machining, die casing, metal stamping [16, 17 and 18]. For most companies the manufacturing system is a valuable asset that is more or less fixed and allows only minor modifications. The product design has therefore to be adapted to the manufacturing system in a larger extent. Hopefully, this will not affect the products functional and performance objective. But sometimes tradeoffs are necessary.

To make these decisions the designer needs knowledge about the existing (and planned future) manufacturing systems and an insight about the system's implication on the product design. Besides the methods, tools and metrics in literature, the companies have to develop their own working practise.

2.2. Design for Producibility

Design for producibility (DFP) is design for manufacturability taken a step closer to the actual manufacturing of a product. As in the same way for manufacturability, there exists no universal definition of producibility. According to [19], producibility is: "The relative ease by which a product can be manufactured as measured in yield, cycle times, and the associated costs of options in product design manufacturing processes, production and support, and tooling." In this work, design for enhanced producibility is the strive for optimisation of product functionality within the manufacturing system constraints and the tradeoffs between product and manufacturing system properties while focusing on enhancing ease of manufacturing.

If production costs and lead time could be automatically calculated based on a process plan generated in accordance with the properties and constraints of the manufacturing system, and the process plan is based on a variant design generated by an automated system for variant design, a decision base for enhanced producibility is obtained. Due to a missing information architecture (standard) for design support, existing tools can not be linked together to accomplish this task [20] and for the companies that want to incorporate this approach one solution is to develop their own systems. For doing so, the view of DFP as depicted in Figure 3 should be adopted.

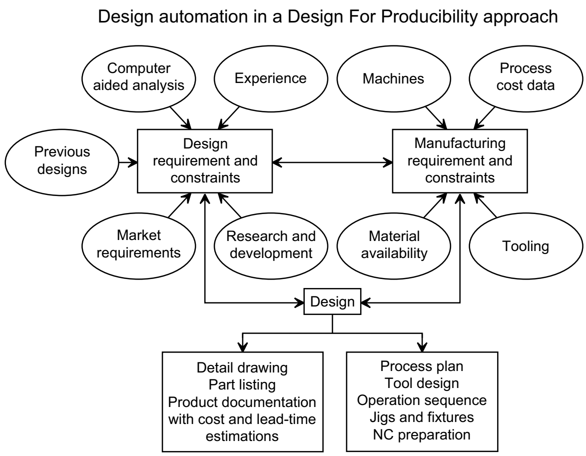

Figure 3. Design automation in a DFP approach, adapted from the view of DFM according to [21].

3. Design Automation

We argue that design automation based on producibility awareness can work as a means for quick and suitable producibility (e.g. cost) estimations of product variants. In this work the terms Computer Support and Design Automation are used synonymously and refer to:

"*Engineering IT-support by implementation of information and knowledge in solutions, tools, or systems that are pre-planned for reuse and support the progress of the design process. The scope of the definition encompasses computerised automation of tasks that directly or indirectly are related to the design process in the range of individual components to complete products.*" – [22]

3.1. Automated design, process planning and cost estimation

The aim of design automation is to support one or more of the areas: design synthesis, design analysis, and plan for manufacture.

Design synthesis involves computerised templates for calculations/optimisation of design parameters, applications for calculation/optimisation and generation of product geometry, applications that ensures producibility, database system supporting reuse of previous solutions, information systems for requirements or manufacturing constraints, configuration systems, etc.

Automated design analysis can be performed as finite element analysis, geometry preparation for finite element analysis, evaluation of producibility, cost estimation, etc. based on a geometry description and/or design characteristics.

Plan for manufacture include computer aided process planning for generation of e.g. operation sequences, production parameters, machine control commands, fixtures and jigs designs, etc. based on a geometry description and/or design characteristics.

Design synthesis can encompass design analysis and plan for manufacture, using their results for further synthesis in a loop towards refined solutions.

3.2. Design Automation Development

In order to create automated design systems one must first categorise the process, design task/s, and problem/s for which the system is intended. Then an appropriate computer implementation can be selected. The process of mapping a problem definition to a suitable solution strategy (related to design automation and computer support) can be divided into four interlinked sub-domains of design automation [23]. Addressing these sub-domains should, ideally, start by breaking down the design process and identifying the domain knowledge linked to it. This is done with the purpose of formulating a problem definition. When the process, its knowledge, and the tasks to be performed are known, the appropriate tools have to be chosen. Following this is the identification and selection of ways of computer implementations.

The four sub-domains are described in more detail as:

- Process character – The design process and its handling of the domain knowledge and design information.
- Domain knowledge – The knowledge that is to be handled in the design process.
- Tools – Suitable tools (methods) that support the handling of domain knowledge and information for the intended solution principals.
- Computer implementations – Suitable computer implementations supporting the identified process character, domain knowledge, and tools.

Design automation systems that are based on this model are mainly subject to be enhanced by analysis driven producibility estimations where design proposals are evaluated after the proposals are made.

In order to perform synthesis driven producibility estimations, where production (and cost) prerequisites are incorporated into the design process, system creation has to be based on an extended model of design automation development incorporating the company “prerequisites and constraints”. This is based on a foundation of producibility awareness as well as on company organisational structure (Fig. 4).

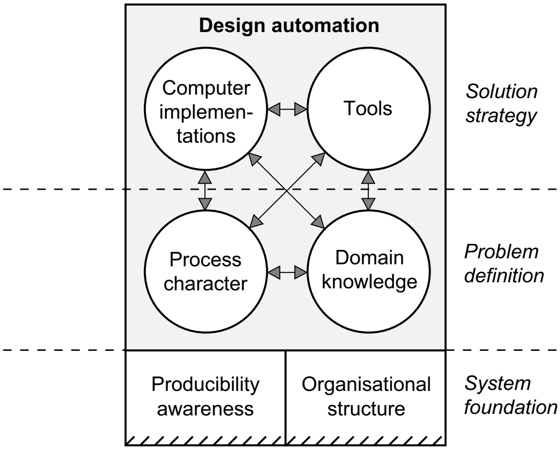

Figure 4. The sub-domains of design automation development, based on a foundation of producibility awareness.

To support the development of design systems, some general criteria that serve as a decision base by weighing system characteristics can be used [24]. Examples of these are: effort of developing, level of investment, level of user readable and understandable knowledge, transparency, scalability, flexibility, longevity, and ease of use. Some of these criteria relate to (or even depend on) knowledge of the entire product development process and, especially, its production aspects i.e. producibility awareness.

4. Procedure for System Development

When creating a design automation system including cost estimation one must determine the variables and parameters that govern the design. By breaking down the design process, the designer is able to find the design parameters that govern the product and from where these parameters originate. These design parameters are extensively transformed through the design process [25] as they are turned into design variables (design process output). Factors that affect the product design and limit the "infinite" design space are: physical limitations, product variant (modularity) limitations, customer specifications, and company production and assembly limitations.

With these limitations (or constraints) the main steps that are suggested for building an automated design system enabling synthesis driven producibility estimations (as well as analysis driven) focus on both customer and product values as well as on fabrication plants values. The steps are:

1. Define customer variables (e.g. force, speed, material, colour, and lifetime) and clarify to what extent they can vary. – Customer space (Fig. 5).
2. Define a resource model containing company variables (e.g. fabrication plant, resources for manufacturing and assembly, and production volume) and clarify to what extent they can vary [26]. – Company design space (Fig. 5).
3. Define product model variables (e.g. model parameters, topology, and configuration) and clarify to what extent they can vary [27]. – Product design space (Fig. 5).

4. Formulate design algorithms, rules and relations that transform costumer and company variables to product model variables and check the design space [28]. – Actual design space (Fig. 5).
5. Define a cost model with a detailing level that is appropriate for the product and the company and identify cost drivers and estimate the cost rate for each [26].
6. Define a process plan model incorporating the assembly sequence, the operations, the operation sequences for manufacturing and assembling of the product, and the manufacturing resources (e.g. work groups and labour) that will be used for the specific product [26].
7. Create product geometry model (representation) that will incorporate identified information needed for an automated system [26 and 29].
8. Build the system with application programs and data repositories [30].
9. Evaluate and improve.

4.1. Design Spaces

To be able to effectively decide how a product and its process is to be modelled and represented, and which parameters are to be considered design variables, the system developers must have knowledge of the entire design process. In addition, it is important to have an understanding of how the product is to be manufactured, since this is an important aspect if the automated variant design system is going to incorporate process planning and synthesis driven producibility estimations.

These design variables and parameters are all connected to different constraint spaces (Fig. 5). Within an "infinite" design space, laws of nature limit what is actually possible to create and produce within the physical design space. Somewhere within these spaces is the customer space representing customer demands and wishes. Limiting the physical design space is the product design space which depends on company configuration of product designs. Finally the company design space based on manufacturing and resource limitations further constraint and limits the number of relevant design proposals within the actual design space.

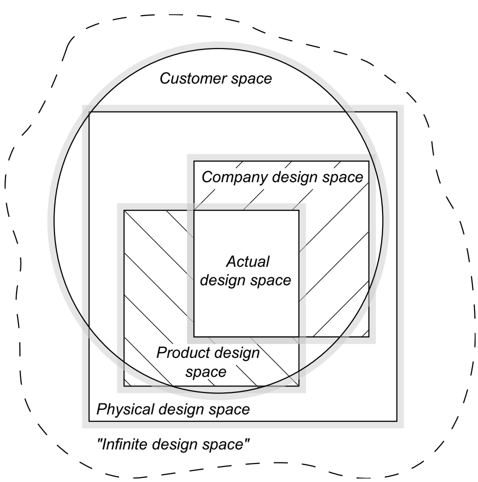

Figure 5. The different design spaces limiting the number of relevant design proposals.

5. Analysis and Synthesis Approach

A traditional and generalised view of the product development process focuses on two main phases of the process at a product solution level, synthesis and analysis, where from an engineering perspective [31]:

- Analysis – is the phase where the product or product part solution is evaluated based on its (intended) physical representation and characteristics.
- Synthesis – is the phase where an identified engineering task or problem definition is addressed in order to find a satisfying solution (optimal at best) based on previous knowledge and expertise.

5.1. Analysis Driven Producibility Estimations

Analysis driven producibility estimations can be applied both manually and automatically to virtually all design proposals. A design automation system not built based on a foundation of producibility awareness will be subject to this approach as producibility and cost assessments will be performed on design proposals in the entire product design space (Fig. 5 and Fig. 6). When applying the company design constraints (production prerequisites) to perform a cost and producibility estimation several of the design proposals which fall outside the actual design space will be eliminated. Since such a system generates both producible and non-producible design proposals, which have to be analysed and evaluated (often by a production engineer), this approach can be time consuming. The workload also increases with the level of product complexity and level of company constraints.

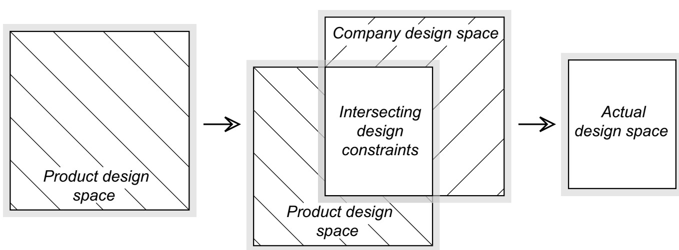

Figure 6. In analysis driven producibility estimation, designs throughout the entire product design space are proposed. By afterwards applying the company design constraints the number of producible design solutions is limited within the actual design space.

5.2. Synthesis driven producibility estimations

In a design automation system based on the foundation of company prerequisites and constraints, the producibility values (or constraints) are an intrinsic part of the design process resulting in a limited number of design proposals, all possible to produce within the actual design space (Fig. 5 and Fig. 7).

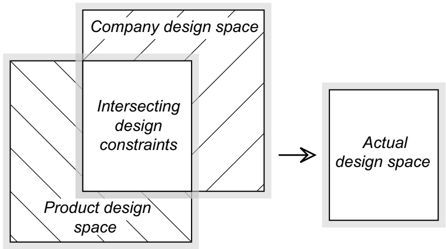

Figure 7. In synthesis driven producibility estimation, company design constraints limit the number of producible designs within the actual design space.

6. Example

An example highlighting the difference between the adoption of analysis and synthesis driven producibility estimations is the CoRPP system [28 and 30] which implements both approaches. The system generates variants of submarine bulkhead sections with short execution time (one run-through takes approximately 2 minutes). This allows for several runs with different conditions to be performed in a short time and with minimal effort. Initially the system did not incorporate manufacturing rules (constraints/requirements). Therefore the results (different product variants) had to be evaluated by production engineers to ensure the different solutions conformability with the manufacturing system. This requires collaboration and information sharing implying higher development costs caused by the use of more time and resources. A manual analysis can also be afflicted with personal judgments and the result of the evaluation can vary from time to time due to the persons involved. To overcome this, the system was further enhanced by adopting the approach of producibility awareness. The opportunity to incorporate manufacturing rules in the system was investigated by studying the influence of a manufacturing constraint on design, cost and weight. A rule was declared in the knowledge base to ensure welding accessibility, one of the high impact cost factors. A constraint concerning the minimum flange distance (Fig. 8) is the rule input. It ensures the accessibility by calculations of the stiffeners flange width and stiffeners height. If the constraint is violated, no solution is generated. This constraints the company design space, but the solutions generated by the system conform to the manufacturing system and they need not to be evaluated by a production engineer. This saves time, reduces costs, and the result is not dependent on personal judgment, leading to a quality assured design process.

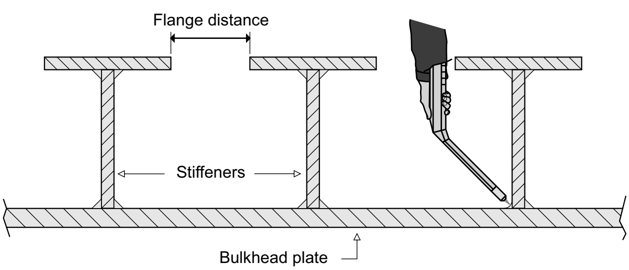

Figure 8. The flange distance is a manufacturing constraint concerning the welding accessibility.

The principal workflows for the analysis driven and synthesis driven approaches are illustrated in Figure 9.

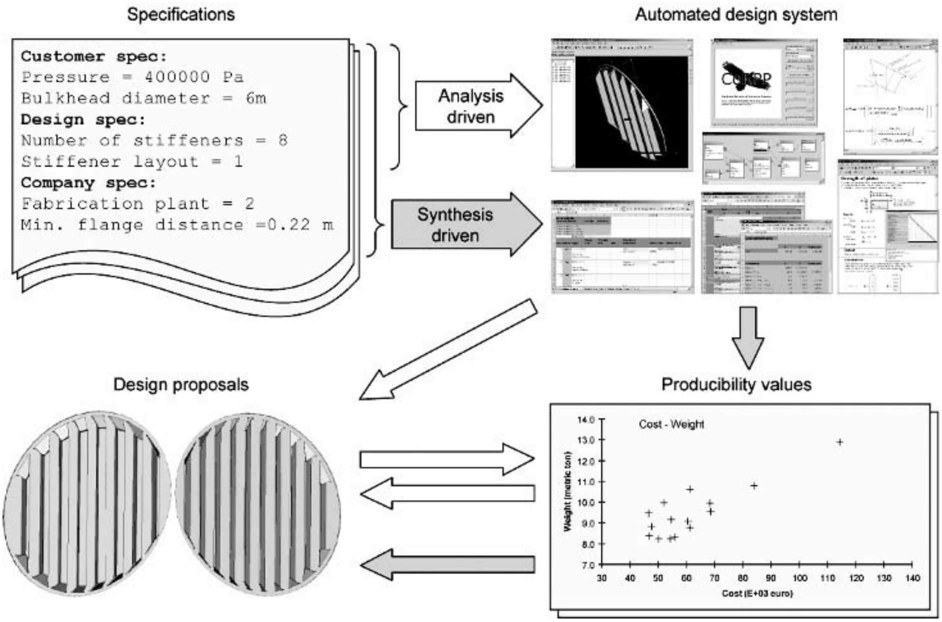

Figure 9. System input in the form of customer demands and manufacturing constraints are feed to the design automation system. In the analysis approach several iterations for manufacturing evaluation has to be made, whereas the synthesis approach generates design proposals already based on the company producibility constraints.

In the analysis driven approach, without the manufacturing constrains, the number of design proposals in the product design space is large and need further evaluation by applying the producibility constraints (Fig. 10A). In the synthesis driven approach the design proposals all conform to the actual design space and need no further evaluation (Fig. 10B).

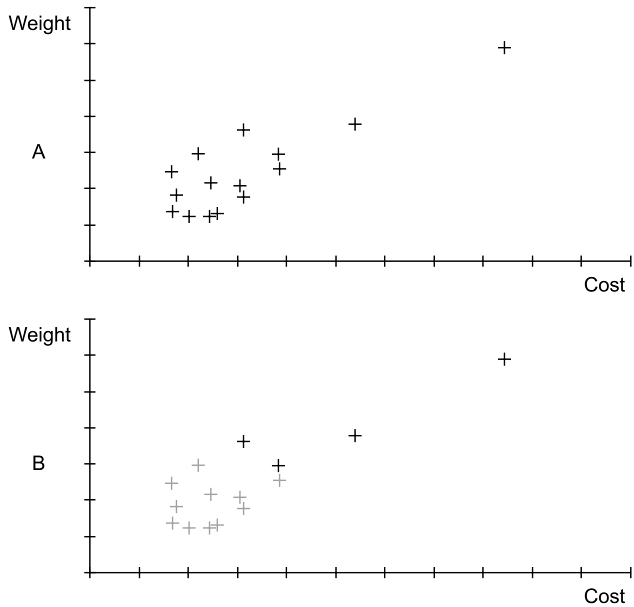

Figure 10. Difference in number of design proposals depending on the application of producibility constraints. Graph A illustrates design proposals within the product design space. Graph B illustrates design proposals within the actual design space

6.1. Investment What-ifs

If the number of product variants the company can offer is restricted by the manufacturing constraints and the production capacity, a synthesis driven producibility estimation tool can be used as a support for decisions regarding investments in new production resources. The implication on the product variety of different alternative enhancements and machines can be studied by what-if scenarios. By changing the rules or the input parameters in correspondence with the characteristics of an intended course of action the effect on the product variety and the market opportunity can be studied and the cost-benefit evaluated. This can be illustrated as going from Figure 10B to Figure 10A. First the manufacturing resources limit the product variety to four variants, but with an investment in new production resources the product variety is expanded and comprises, in this illustration, fifteen solutions.

7. Key Conclusions

To implement a design automation system that supports early cost estimations and generates producible design proposals, the system development must be based on producibility awareness following a formalised procedure to determine the variables and parameters that govern the design (Paragraph 5). Such a system would conform to the principal of synthesis driven producibility estimations that proactively limits the number of design proposals within the actual producible design space. This allows for saved time and recourses that would otherwise be spent on analysing design proposals that fall within the product design space but outside the company design space due to

producibility capacity limitations. A system incorporating producibility awareness and synthesis driven producibility estimations could also be used as a tool for strategic decisions on recourse investments by the use of what-if scenarios.

Acknowledgements

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Incorporating cost analysis in a multi disciplinary design environment for aircraft movables

A.H. van der Laan[1] and M.J.L. van Tooren[2]
Delft University of Technology, The Netherlands

Abstract. The design and production of aircraft structures is a highly cost driven industrial activity. Advanced, more reliable cost estimation techniques can help to improve competitiveness and reduce risk in the bidding phase. In this paper a design support framework will be presented that offers improved information and knowledge about new designs in an early stage of the development. The paper focuses on aircraft movables like rudders, elevators or flaps, but similar frameworks can be built for other product families. The framework is based on the Design and Engineering Engine (DEE) architecture. The DEE formalizes the basic design cycle and comprises a Multi-Model-Generator (MMG) based on Knowledge Based Engineering principles that creates a smooth link between a parametric product model and different analysis tools, including a cost analysis tool. It will be shown that such an MMG can support the extraction of a cost engineering view on the product model that can be used in combination with proper Cost Estimation Relations to have more reliable cost information in an early stage of the design process.

Keywords. Cost estimation, Multi disciplinary design, Knowledge based engineering

Introduction

During the design of new aircraft movables, predictions of the performance of the different design concepts are used to select the best design. This performance usually entails performance in the area of weight, aerodynamics, manufacturability and costs. At the conceptual design stage in-depth analyses using sophisticated computer tools are performed in the areas of aerodynamic and structural performance. Compared to these analyses the manufacturability and cost analysis are normally primitive[1]. Often a cost estimation based on cost per kilo is performed. Such an estimation based on weight does not incorporate important manufacturing factors like complexity to properly compare different design concepts. These factors can, however, significantly influence the manufacturing cost of the design[2]. The manufacturing analysis is usually limited because at this early stage of the design process, information available for a manufacturing analysis is limited[3]. Preferably a more in depth manufacturing analysis

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[1] Phd student, Design, Integration and Operation of Aircraft and Rotorcraft, PO box 5058, 2600 GB, Delft, The Netherlands, A.H.vanderlaan@lr.tudelft.nl
[2] Professor, Design, Integration and Operation of Aircraft and Rotorcraft

should be performed, especially because manufacturability performance will determine the profitability of the project to a large extent and the total manufacturing cost within the project are determined early on in the design process[4].

The issue of limited data available for manufacturing analysis can be solved by automatically generating this data during the conceptual design phase. This generation of data can be done by using a Design and Engineering Engine (DEE)[5]. With such a DEE, designs can automatically be generated and evaluated. At the heart of a DEE is a parametric Multi Model Generator (MMG) that creates a model of the analysed entity based on input parameters supplied by the model user. This model consists not only of geometry but also of other information such as a manufacturing concept. The MMG provides an automated smooth interface between the product model and the analysis tools to eliminate time consuming[6] manual data transfer.

1. Cost estimation method selection

Different techniques exist for cost estimation, each with its own specific characteristics, advantages and disadvantages. The characteristics of these cost estimation methods can be found in Curran[7]. The three main techniques are:

- *Analogous cost estimation*. Product cost is estimated by comparing it to previously produced similar products
- *Parametric cost estimation*. Product cost is linked to technical parameters such as weight, size or part count using statistical relations.
- *Bottom up cost estimation*. In this approach the cost of all entities in the Work Break Down Structure of the product are determined

When choosing which cost estimation technique to use in the DEE several aspects have to be considered. First of all the cost estimation should generate viable results for innovative production methods. This means that cost estimation techniques based on historical product data are not very suitable. Secondly the advantages of the availability of a detailed parametric product model should be exploited. The DEE can generate detailed manufacturing data with relatively little effort. Taking into account both these aspects, bottom up costing was chosen as the cost estimation method. More specifically a bottom up cost estimation method based on manufacturing process characteristics was implemented.

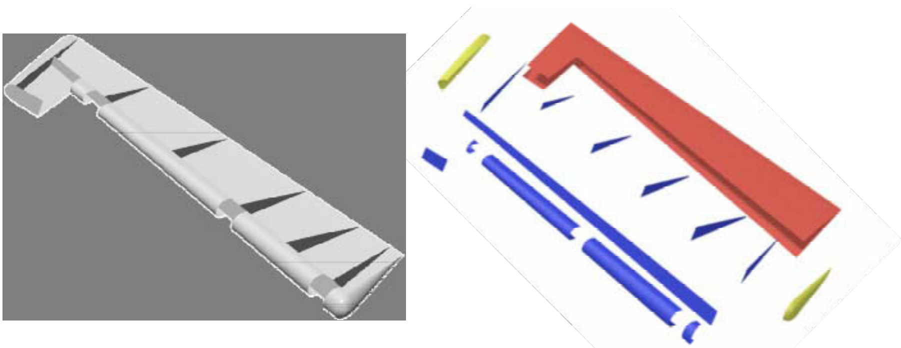
The process based bottom up method has the advantage that the cost estimation relations used relate attributes describing the manufactured product to process characteristics, such as process times, that can be translated directly to manufacturing cost. This offers the advantage that the relations used can be related to the actual process physics of the manufacturing process, making this method and its results more understandable and accessible than cost estimation methods based purely on statistical relations. Keeping the results understandable is key in gaining the acceptance of the method by DEE users, which are usually not cost estimation experts.

2. The movable multi model generator

The multi model generator part of the DEE will have to generate the data needed for the cost analysis module. To do this first a model has to be created from which the

data needed can be extracted. An aircraft movable is an aircraft part that can be actuated in flight to disturb the airflow around the aircraft. Examples are elevators, rudders, ailerons and flaps. A movable multi model generator, called the Parametric Movable Model (PMM), that incorporates a parametric product model for this product family has previously been developed for a DEE that supports the automated structural analysis of such components[8]. Based on a product specification expressed in parameter values, the PMM creates several views on the movable, e.g. a geometrical view, a loads view and a structural view. These views contain information about the structure, such as the thickness of certain parts and information about the loads acting on the movable The PMM is built using the ICAD software package. The ICAD system is a Knowledge Based Engineering (KBE) tool produced by Dassault Systèmes. The PMM creates a model of a movable, using methods (i.e. rule bases) stored in the model and input parameters provided in a text file by the user. The PMM works in such a way that an outer shape and an inner structure of any movable can be generated by the model. A typical example of a movable created by the PMM can be seen in Figure 1.

Initially PMM was developed to support a structural analysis and therefore only features and elements needed for the structural analysis were generated. These elements include surfaces that determine the outer geometry of the movable representing the movables skins and elements representing the inner structure such as ribs and spars. Each element is identified by its structural function. For the cost analysis this structural function is not of interest though. For the cost analysis it is necessary to have a representation of the manufacturing concept of the movable. This is why a new view was added to the PMM, the manufacturing view.



Structural view of a movable created with the PMM **Manufacturing concept determining the different parts**

Figure 1 Two elements of the Parametric Movable Model; the structural model and the different parts representing the manufacturing concept

In the manufacturing view the surfaces that represent the structural entities are re-used. However to represent the manufacturing concept they are reordered. To do this first the manufacturing concept has to be devised. This is done by adding input parameters. These input parameters determine how structural elements should be combined into so called manufacturable parts. In this way complex manufacturable parts can be specified that are created by combining the existing structural elements. These manufacturable parts can be used to generate the data needed for the cost analysis. An exploded view showing the manufacturable parts of a general aviation rudder can be seen in Figure 1.

The second basic elements of the manufacturing view are the assembly joints. These assembly joints are the elements that represent the connections between

manufacturable parts. The generation of these elements does not require any extra geometric input parameters for the PMM. Instead the capability has been added to the PMM to scan the different manufacturable parts and determine where the different parts meet and should be connected.

Defining a manufacturing concept for a movable does not only consist of reordering the structural elements. The manufacturing and assembly methods used for the manufacturing of the movable also have to be defined. In case of the manufacturable parts a manufacturing method, a material and a material thickness have to be specified for each part. If the same approach would be used to define all the assembly methods the amount of input parameter could explode because the number of assembly joints is usually larger than the number of manufacturable parts. Therefore another approach was selected. The assembly method is determined by preferred material or manufacturing method combinations, this resembles common practice in the aircraft industry.

The surface groups representing the manufacturable parts and curves representing the assembly joints that have been created can be used to extract information for the manufacturing cost analysis. For instance, the outer boundary of a surface group can determine blank size while non-tangent inner boundaries within a surface group can be used to determine the complexity of that part. Other information that can be exported include: curvature of assembly joints, curvature of part surfaces, assembly joint lengths, assembly joint type and part manufacturing type.

The information is written into reports that can be read by the cost analysis module. These reports must have a generic format so when the tool that uses the information changes only the interface of the analysis tool has to be adjusted while the reports stay the same. The reports should also be accessible and understandable independent from specialized software. Therefore the generic XML-file type was chosen for these report files.

3. Implementation of the cost estimation analysis module

The cost analysis module will perform a cost analysis using the XML-datafiles produced by the PMM. The chosen cost estimation method is the bottom-up method using Cost Estimation Relations (CER's) based on the process physics of the manufacturing processes. The cost analysis module itself consists of several different elements, a schematic overview of the cost analysis can be seen in Figure 2. In this figure the flow of data within the cost analysis process can be seen. The cost estimation is performed for each manufacturable part and assembly joint using CER's that are stored in function libraries. Another important element is the manufacturing database. This is essentially a digital representation of the manufacturing environment in which the cost analysis will be performed.

In the cost estimation process the manufacturing process of each manufacturable part or assembly joint is split into elementary manufacturing processes. Therefore each production or assembly process has to be split into elementary sub-processes. One of the advantages of looking at sub-processes is that many manufacturing processes share many sub-processes and the CER's of these sub-processes can therefore be re-used.

Due to the modular build-up of the cost estimation tool, the number of sub-processes that are involved in the manufacturing process can be easily adjusted. It is also possible

to eliminate or substitute certain sub-processes to study the effect of limitations or innovation in the manufacturing capabilities.

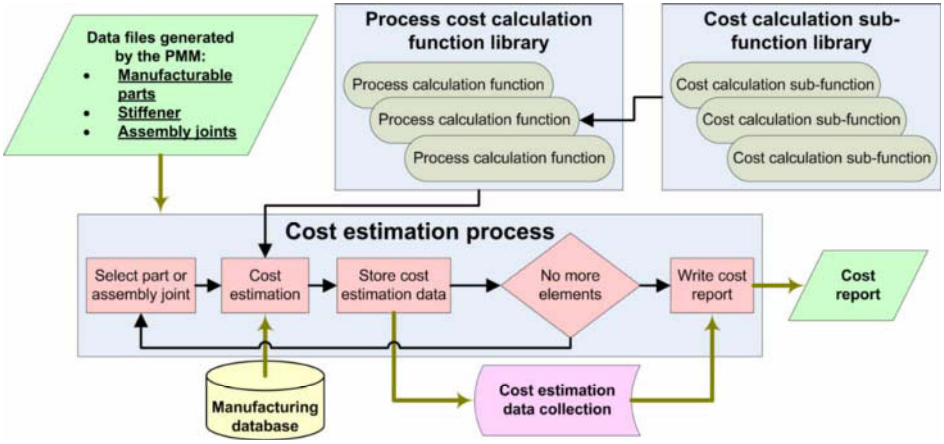


Figure 2 Schematic overview of the cost estimation process implemented in the cost analysis module

3.1. Cost analysis functions

The CER's stored in the cost estimation libraries are based on the principle of capturing the process physics of the sub-process in a formula. The formula chosen as representing the process physics is the hyperbolic function[9].

$$t = t_{delay} + \tau_0 \sqrt{\left(\frac{x}{v_0 \cdot \tau_0} + 1\right)^2 - 1} \qquad (1)$$

$x =$ Variable on which the cost estimation is based, for instance area or volume
$t_{delay} =$ Delay time in the manufacturing operation
$v_0 =$ Steady state speed of the manufacturing process
$\tau_0 =$ Time it takes to reach 63% of the steady state speed

The three attributes describing the physics of the manufacturing sub-process are input parameters for the cost estimation and are stored in the manufacturing database. For many processes the values of these three attributes are available in the public domain. There are also methods of determining these three attributes. First of which is the manufacture of test samples using the manufacturing method for which the attributes should be determined. Second method is the determination of the attributes from other process attributes. For instance the steady state speed of a milling machine will to a large extent determine the steady state of the milling manufacturing sub-process. Although the attributes of many of the sub-processes are available in the public domain, for a properly functioning and up to date cost estimation tool they have to be calibrated and maintained. Calibration means that the attributes should be based on the processes that are actually used in a particular company or factory. Maintenance means that the attributes should be kept up to date to reflect changes in the manufacturing sub-process of the factory or company where it is used.

When both the process attributes and determining variables of all production sub processes involved in producing the parts that form the aircraft component and the

assembly sub processes to assembly those parts are known, the total process time of the aircraft component can be determined. The sub-process times can also be used to determine some of the consumed resources, such as labour hours and machine hours. The calculation of the amount and type of materials used in the different sub processes requires a different approach. Here the geometric data available is translated directly into material amounts which later can be used to determine the total material price.

3.2. Manufacturing database

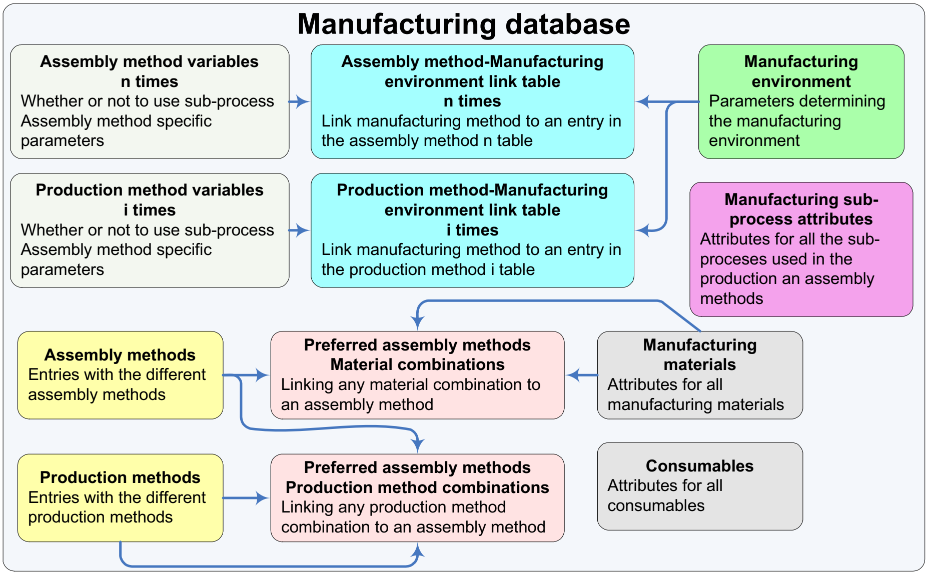


Figure 3 Graphical representation of the manufacturing database showing all the tables

In the manufacturing database additional input parameters for the cost estimation process are stored. These input parameters have no influence on the design concept of the movable itself but purely define the manufacturing environment in which the cost analysis is being performed. There is an exception to this statement though because the material and manufacturing method combinations that determine the assembly methods between the manufacturable parts are also stored in the manufacturing database. They are stored here because they are the responsibility of the manufacturing engineer and not of the design engineer that is using the DEE. The actual contents of the manufacturing database can be seen in Figure 3.

Using the manufacturing database the inputs defining the manufacturing environment are kept separate from the inputs determining the movable design concept. This ensures that the different concepts are analysed in a consistent manner that follows normal practice in industry. On the other hand it can also be used to determine the optimal manufacturing environment for a given movable design concept. Another advantage is that the manufacturing database can also be used by other DEE's or cost analysis tools. Like the reports produced by the PMM accessibility of the manufacturing database is essential to ensure transparency of the cost analysis process. Therefore the manufacturing database is implemented as a MySQL database which is accessible by any common internet browser.

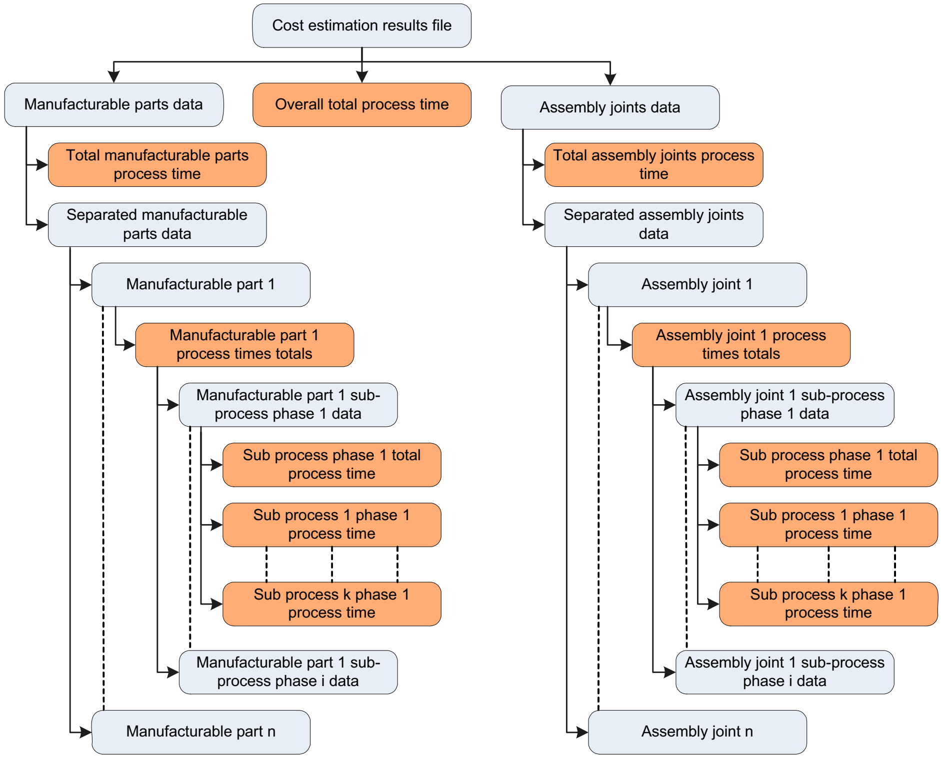


Figure 4 Schematic overview of the process time part of the cost estimation results file. Orange elements represent actual process times

3.3. Cost analysis result representation

The cost analysis performed by the cost analysis module results in a cost analysis report. In this report the results of the cost analysis of all the sub-phases and sub-processes of all the manufacturing processes used to produce the movable are stored. There are quite a few manufacturing sub processes in the manufacture of a movable. Therefore the amount of data produced by the cost analysis module is quite big. To keep the results accessible it has to be represented in a smart way. This is done firstly by choosing the right file format, in this case again the XML-file format was chosen. However, representing the data in a structured informative way does not solve all the problems. It would for instance be very difficult to determine the total cost of the movable design concept just by looking at the cost data from the different sub-processes. On the other hand this sub-process data might come in handy when looking at the cost drivers of a certain manufacturing process or when checking the validity of the cost model. Therefore the results should be presented on multiple levels. This means that the software tool or person interpreting the results can zoom to different levels. At the highest level would for instance be the overall cost of the movable while the lowest level represents the cost of a single sub-process. In Figure 4 a representation of the multi level results in process time estimation can be seen. Besides the cost estimation results the interpreter might also want to put the results into context

therefore characteristics describing the manufacturable parts and assembly joints are also presented in the cost analysis results file.

4. Conclusions and future developments

A method has been developed to incorporate cost analysis in a multi disciplinary design environment for aircraft movables. The developed cost analysis method uses data created by a movable model generator. The model generated entails more then just a geometrical model. Therefore manufacturing data can be extracted and used for the cost analysis. Because of the availability of this data a relatively high fidelity cost analysis method based on manufacturing process physics can be used. This high fidelity method results in detailed cost analysis results at an early stage of the movable design process. By making all the tools and data transport entities involved in the cost analysis transparent and accessible, the cost estimation process can be monitored and the cost analysis results become understandable and more acceptable for people involved in the design process that are not cost estimation experts.

In the future the cost analysis module will be expanded. More manufacturing methods have to be modelled and more cost aspects of these manufacturing methods have to be incorporated. Furthermore the cost analysis results have to be made comparable, meaning that, using labour and machine rates, the process times should be converted to currency amounts. Finally the cost analysis module should be continuously calibrated and updated to include changes to existing manufacturing methods.

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Identifying the key factors affecting the quality of a cost estimate

Evaggelos Lavdas[1], Rajkumar Roy and Charles Wainwright
Department of Manufacturing, Cranfield University, United Kingdom

Abstract. This paper provides an insight into the issue of what constitutes quality of a cost estimate. A survey has been carried out, in order to identify the key attributes of a good quality estimate. The cost estimators who took part in this survey come from various disciplines, industries, and geographical locations. Twenty-three characteristics believed to contribute towards a good quality estimate and sixteen metrics which could be potentially used to measure a cost estimate's quality, have been identified. Some characteristics are universal in nature and were expressed by a large number of participants, independently of the purpose and application of the estimate. In contrast others are specific to individuals' needs, environment and cost estimating purpose. Differences have been identified, in terms of expectations as to what a good estimate is, between two distinct groups; cost managers against cost estimators with non-managerial position. It has also been identified that the amount of experience in the area of cost estimating is a factor that influences those expectations.

Keywords. Cost Estimating, Cost Engineering, Quality of Estimate

Introduction

Cost Estimating is a highly subjective process [1, 2, 3] and an estimator would often apply expert judgement in conjunction with another cost estimating technique in order to carry out a cost estimate [4]. For that reason it is difficult to formulate a universal definition of what a good quality estimate is. The word quality is usually associated with a level of excellence or a distinguishing characteristic of a certain thing. However, quality itself is of subjective nature and it is quite possible that different people may have varying opinions about whether something is of good quality or not.

Organizations have come to realize that by controlling and enhancing the quality of their estimating process, cost overruns could be potentially reduced or, at the worst case, predicted in advance of occurring so that appropriate actions could be taken. As a result, a survey has been carried out across a sample of cost estimators in order to identify the key attributes, which contribute towards a good quality estimate. The overall aim of this study is to reach a consensus between cost practitioners about what quality of a cost estimate should be about, and how it could be measured.

[1] Corresponding Author: Department of Manufacturing, Cranfield University, MK43 0AL, UK; Email(s): E.Lavdas@cranfield.ac.uk, R.Roy@cranfield.ac.uk or C.Wainwright@cranfield.ac.uk

1. Related Research

A study has been carried out by Grant [5] in order to identify the skills, knowledge and competences necessary for a cost engineer. As part of this study a survey took place where cost estimators were asked what they believe a good estimate is. Some of the main points that have been captured are the understanding of assumptions and documentation, a well defined product, enough time to complete the estimate and accuracy to the actual cost incurred. Others included the inclusion of risk analysis the use of justifiable and sound data. Similarly in another survey, Akintoye *et al.* [6] found that inaccuracy in cost estimating is related to the lack of practical knowledge, insufficient time to prepare the estimate and poor documentation.

Both Curran [7] and Jorgensen [8] mention the importance of assessing the uncertainty while carrying out a cost estimate, and the former adds that reasoning with risk should be part of the estimate itself. Documentation is one of the characteristics that is usually mentioned when the issue of producing good quality estimates is concerned [1, 9, 10]. It is widely accepted that documentation is a crucial part towards supporting an estimate, and it contributes towards the estimate's credibility. Beltramo [1] adds that not only supporting documentation to an estimate is important, but also the documentation of the methodology followed in order to carry out an estimate.

2. Research Methodology

An electronic-mail survey was chosen as a research method to carry out this study for the reason that interviewing would be difficult to implement in terms of time and recourses. In addition to that, a survey allowed the collection of more individual opinions and the authors were able to reach individuals from a variety of geographical locations. Questionnaires were sent to the participants, all of which were known to be cost estimation practitioners.

2.1 Questionnaire Design

The first section of the questionnaire consists of open-ended questions, designed to capture the opinions of the respondents on the subject of quality in cost estimating. The second section of the questionnaire consisted of seven semantic differential scales; one per each pre-defined characteristic. Those seven pre-defined characteristics have been identified both through literature and through the author's experience, as being important towards the achievement of a good quality estimate. Each scale is a representation of one characteristic, and the participants were asked to rate each characteristic in terms of importance to the overall estimate quality.

Following a preliminary analysis of the answers of the respondents, it was found that the usable responses for analysis amounted to 26 completed questionnaires. The response rate was estimated as 41%. The authors have taken also into account Robson's [11] consideration to focus not only on the response rate but also on the representativeness of the sample.

Table 1. Sample distribution based on the participants' experience in cost estimation.

Groups (years of experience)	Number of Participants	Percentage of overall sample	Mean (years of experience)	Standard Deviation
3 – 6	5	19.23%	4.8	1.304
7 – 11	4	15.38%	10	0.816
12 – 20	6	23.08%	18.8	1.789
21 – 25	4	15.38%	24.25	1.500
26 and over	7	26.92%	31.4	2.191

2.2 Survey Sample

The sample, which the analysis of this study is based on, is consisted of 26 usable responses. The largest percentage of the respondents is coming from the aerospace industry and accounted for the 42% of the overall sample. The rest of the industries represented are, the automotive industry with 16%, the energy industry (nuclear, oil & gas) industry with 15%, the consulting sector with 12%, the naval/marine industry with 11% and finally the heavy machinery industry with 4%. The majority of the participants who took part in this survey are coming from the civilian industry sector, with only 26% of the sample working for, or being directly related to, the defence sector.

The participants in this survey have been asked to state their experience, in years, in the area of cost estimating. Table 1 presents the various levels of experience which the respondents have. It has to be noted that 81% of the sample is consisted of experienced cost estimators with a lot of years of hands-on industrial experience. The sample represents a good experience distribution, from junior cost estimators to highly experienced ones. (overall mean = 18.7 years, standard deviation = 10 years).

The cost estimators who took part in this survey came from a variety of geographical locations. Participants from the United States accounted for the 12% of the sample, with the remaining 88% coming from Europe. Participants coming from the United Kingdom accounted for the 76% of the whole sample.

3. Results and Analysis

The answers of the participants to the open-ended questions were reviewed and filtered based on their similarities, differences and uniqueness. Each individual point (for example a characteristic or a metric) was noted down, for all participants. At the end it was found that a number of participants would mention the same point, so similar answers were grouped together along with the frequency of how many times those individual points have been mentioned in the survey.

3.1 Cost Estimate Types and Techniques Used

Table 2 presents the answers of the participants, when asked to state what types of estimates they usually carry out in their everyday job. It should be noted that a cost

Table 2. Types of estimates carried out by the participants.

Type of Estimate	Percentage of Participants
Rough Order Magnitude (ROM)	53.85%
Bid & Proposal Analysis	50.00%
Should Cost	42.31%
Budget	30.77%
Fixed Price Estimates	19.23%
Supplier Evaluation	15.38%
Value Engineering & Value Analysis	7.69%
Trade Studies	3.85%
Other	11.54%

estimator may usually carry out as part of his job, a number of different types of estimates. Thus, the percentages in table 2 represent the number of the participants that stated to carry out this type of estimate, out of the total number of participants in this survey.

The participants have been asked to state which estimating technique they usually utilise to carry out their estimates. The detailed (bottoms-up) technique has been mentioned by 84.6% of the participants. The analogy technique has been mentioned by 57.6% of the participants. The parametric technique achieved the same percentage value, while the Activity Based Costing technique was mentioned only by 11.5% of the participants.

3.2 The Characteristics of a Good Quality Estimate

The participants have been asked to list the characteristics, which they believe to define a cost estimate of good quality. Table 3 presents the characteristics which have been identified by the participants. Similarly, the participants have been asked to list the metrics, which they believe could be used in order to measure whether a cost estimate is of good quality, or not. Table 3 presents the metrics which have been identified by the participants.

Twenty-three characteristics have been identified by the participants. Documentation is one of the characteristic that has been mentioned by the majority of the participants in this survey, as being paramount towards a good quality estimate. Other characteristics refer to the use of risk analysis, a clear presentation of the estimate and the results, the level of accuracy based on the business need and the transparency of the cost estimate. In general, the characteristics that have been identified cover all aspects of cost estimate development; from the estimate itself and its background data and conditions, to documentation, risk analysis and validation.

Out of the 16 metrics identified some of them are quantitative in nature, such as checking estimate accuracy with actual costs, checking against other estimates/models and compare estimated costs with market alternatives. Some others are qualitative in nature, such as gauge how the supplier responds to the estimate, review the assumptions made, check the consistency of the estimate and check the quality of

Table 3. The 23 characteristics and 16 metrics identified by the cost estimators.

Characteristics of a Good Estimate
Documentation of Rules & Assumptions
Full breakdown (incl. labour, BOM, sub-contractor involvement)
Shows clearly defined Scope of Work/Specs
Use of risk analysis (cost sensitivities due to risk) - probabilistic estimate
Simple & Clear Presentation of results (clarity)
Auditable - Transparent (within confidentiality clauses)
Accuracy in-line with business need
Based on a 'similar to' product (use of actual known costs - sanity check)
Based on valid quotes for purchased content
High level of technical detail
Consistency
Repeatable
Documentation of Data Sources
Supplier (or other parties) buys-in the model
Formal Structure - followed a defined process to generate the cost estimate
Reliable data sources (accurate & up-to-date data)
Manufacturing quantity & rate
Economic period of costs
Estimating method appropriate to final use of estimate - (effort spent to create an estimate)
Documented Basis of Estimate (BOE)
Benchmarked in the industry
The Cost Estimate summarizes the Main cost elements
Identification of cost drivers (for cost reduction purposes)

Metrics to Assess Quality
Use Actual from similar programs/parts - historical data
Similar Estimates/Cost models (validated)
Check accuracy (against actual cost)
Benchmarking & Market test studies (and/or compare with vendor quotes)
3 point principles (check with other cost estimating methods)
Credibility of Source data (also check quality of information/knowledge used)
Check consistency - consistent formal approach
Check auditability
Let expert(s) validate major assumptions made
Gauge how the supplier responds to the estimate
Metrics such as cost divided by weight
Access to the Basis of Estimate
Check quality & detail of supporting documentation
Check assumptions made (logic, realistic and basis)
Maintain estimate snapshots throughout lifecycle of product
Allow peer review

supporting documentation. Qualitative metrics as such are difficult to quantify and solely depend on the subjective interpretation of the individual who makes use of them.

3.3 Analysis of the Ratings of the 7 Characteristics

In the second section of the questionnaire the participants have been asked to rate seven pre-defined characteristics, in terms of how important they think a particular characteristic is towards what would be considered a good cost estimate. The characteristics that were presented to the participants are: (a) 'Estimate Accuracy', (b) 'Sufficient Documentation', (c) 'The Use of justifiable Cost Data', (d) 'Inclusion of Risk Analysis', (e) 'Well Defined WBS', (f) 'Recording Assumptions' and (g) 'The Inclusion of Uncertainty'.

The overall results for the rating of the seven characteristics, in terms of importance as rated by the participants, can be found in Table 4. The values in table 4 represent the mean values as percentages, of all the participants' ratings. The

Table 4. Mean results of the 7 characteristics, for the whole of the sample.

Characteristic	Importance (%)
c. Using Justifiable Cost Data	92.86%
b. Sufficient Documentation	90.91%
f. Recording Assumptions	90.91%
e. Well defined WBS	83.12%
a. Estimate Accuracy	79.22%
d. Include Risk Analysis	72.08%
g. Including Uncertainty	70.13%

Table 5. Presented results for three identified groups, part of the overall survey sample.

Characteristic	Importance (%)		
	3 – 6 years Sample	3 – 11 years Sample	11 + years Sample
(a) Estimate Accuracy	89.29%	81.63%	78.57%
(b) Sufficient Documentation	96.43%	89.80%	90.82%
(c) Justifiable Cost data	85.71%	87.76%	94.90%
(d) Include Risk Analysis	64.29%	65.31%	73.47%
(e) Well defined WBS	96.43%	81.63%	85.71%
(f) Recording Assumptions	100.00%	93.88%	88.78%
(g) Including Uncertainty	64.29%	71.43%	67.35%

characteristics of ‘Using Justifiable Cost Data’, ‘Sufficient Documentation’ and ‘Recording Assumptions’ have been rated particularly high compared to the rest.

3.3.1 Results Based on Experience

The next step was to compare the ratings of the participants, based on their level of experience as a cost estimator. Table 5 presents the average results, based on cost estimating experience, of three distinct groups, part of the overall sample.

The group of 11+ years have rated with the highest score the characteristic (c) ‘Using justifiable cost data’. In contrast, the group 3–11 years have rated characteristic (f) ’Recording Assumptions’, with a highest score. Remarkably the group 3–11 years, place characteristic (c) ‘Using Justifiable Cost Data’ as *third* in their order of importance, while the group of 3-6 years place that characteristic fifth in the order of importance. The difference in importance of characteristic ‘Justifiable Cost Data’ between the 11+ group, to the rest two, is nearly 10%.

The 11+ years group place more importance on the inclusion of risk analysis, when compared to the 3-6 years group and the 3-11 years group. Based on the results of table 5, the importance placed on the ‘Estimate Accuracy’ decreases, while the cost estimating experience increases. This implies that more experienced cost estimators place less importance on the actual estimate accuracy, as a measure of quality, than their less experienced counterparts. The 3-6 years group seems to place much higher importance on the characteristics of ‘Well defined WBS’ and ‘Recording Assumptions’, than the other two groups do. The same group is the only one that rates

Table 6. Survey Results of Managers versus Non-Managers.

	Managers	Non-Managers	Difference
(a) Estimate Accuracy	82.14%	78.57%	3.57%
(b) Sufficient Documentation	92.86%	90.48%	2.38%
(c) Justifiable Cost data	100.00%	91.27%	8.73%
(d) Include Risk Analysis	67.86%	73.02%	5.16%
(e) Well defined WBS	82.14%	84.13%	1.99%
(f) Recording Assumptions	92.86%	90.48%	2.38%
(g) Including Uncertainty	75.00%	69.05%	5.95%

the estimate accuracy so high compared to the other two, with a difference of around 10% against the 11+ years group.

3.3.2 Managers versus Non-Managers

23% of the sample holds a managerial position, either as head of department or as team manager/leader. As a result they would typically supervise cost estimators who would prepare estimates for them, or at the very least review their work at some level. The following analysis took place in order to understand whether there is a difference in perspective in their answers, depending on whether the participants have a managerial position, or not.

Looking at table 6, both groups follow a similar pattern as far as the order in which they have rated the characteristics, in terms of importance, is concerned. Both identified the characteristic of 'Using Justifiable Cost Data' as the most important characteristic against the other six remaining. Overall the group of managers has rated higher all the characteristics, when compared to the group of non-managers, with the exception of the characteristics of 'Well Defined WBS' and the 'Inclusion of Risk Analysis'. In general, the group of managers has placed higher importance on characteristics that have to do with documentation and any supporting information to a cost estimate. They also place more importance on the actual estimate accuracy, than the group of non-managers, as being a characteristic towards a good cost estimate.

3.3.3 Comparison of the Defence versus the Civilian Sector

Table 7 presents the results of the ratings by dividing the sample into two groups; cost estimators from the defence sector and ones from the civilian sector. Cost estimators from the defence sector have unanimously identified as the most important characteristic, the one of 'sufficient documentation' with a 100% rating. In addition, the defence sector seems to rate the 'inclusion of risk analysis' and the 'inclusion of uncertainty' higher than their civilian colleagues. Overall, it seems that the defence sector places a high importance on documentation and risk. The remaining results between the two groups do not show any noticeable anomalies.

4. Discussion

As a result of this study, 23 characteristics have been identified that are thought to be

Table 7. Survey results of the participants coming from the civilian sector versus their defence counterparts.

	Defence	**Civilian**	**Difference**
(a) Estimate Accuracy	78.57%	78.99%	0.42%
(b) Sufficient Documentation	100.00%	88.24%	11.76%
(c) Justifiable Cost data	90.48%	92.44%	1.96%
(d) Include Risk Analysis	73.81%	69.75%	4.06%
(e) Well defined WBS	85.71%	83.19%	2.52%
(f) Recording Assumptions	92.86%	90.76%	2.10%
(g) Including Uncertainty	71.43%	68.07%	3.36%

present in a good quality cost estimate. In addition to that, 16 metrics have been identified by the participants of this survey, which could be potentially used to check the quality of a particular cost estimate. Some of those metrics are easily measurable, while some others are harder to measure due to being more generic and qualitative in nature.

When comparing the seven pre-defined characteristics, three score the highest out of the entire sample. Those were the 'use of justifiable cost data', the provision of 'sufficient documentation' and the 'recording of assumptions'. It is observed that the group of estimators with more experience place more importance on the inclusion of risk and uncertainty in a cost estimate, when compared to their less experienced colleagues. In addition, they place less importance to the actual estimate accuracy, while they have identified as the most important characteristic the use of justifiable cost data (something that their less experienced colleagues ranked as only fifth).

Out of the results of the comparison between the managers and non-managers it was found that both groups follow a similar pattern; both ranked the same characteristics, with the same order of importance. However the group of managers rated those much higher than the other group. Considering that those characteristics relate to documentation and supporting information (provided with an estimate), the result does not come as a surprise. When an estimate is presented to a manager, the manager would usually require supporting documentation to the estimate. The reason is that managers need evidence in order to be convinced that the estimated cost will be close to the real cost, without having to go through and understand the whole cost estimate. Finally, something that should be noted is that the managers place more importance on the estimate accuracy, when compared to the non-managers group. The managers being responsible for the shortcomings of a project, it is natural to require accuracy of the estimates on which they base their decisions.

Finally the answers coming from the defence industry were compared to their civilian counterparts. The defence group has unanimously identified the provision of 'sufficient documentation' as the most important characteristic (with maximum points awarded by each individual belonging to that group), while the civilian industry has ranked as first the use of justifiable data. In addition, the defence industry places more importance on the inclusion of risk and uncertainty, when compared to the civilian group. The reason could be the more stringent procedures that cost estimators who work for the defence sector have to adhere to.

5. Conclusions

The research has identified a list of factors that affect the quality of a cost estimate and a library of metrics that could be potentially used to quantify how good a cost estimate is. Further work is required in order to quantify the relative influence that these factors and metrics have on the overall quality of the estimate. It is observed that managers place more importance on the issues of estimate accuracy and documentation, than non-managers. It has also been found that cost estimators from the defence sector place a lot more importance on documentation, than estimators from the civilian sector.

Overall, the findings of this study could be considered to be in accordance with general beliefs and known facts across the domain of cost estimation. It was shown that the perspective, as to what a good quality estimate is, changes depending on the estimator's experience, position and sector origin. Further work is going to follow where the results of this survey will be used to develop a checklist. This study will lead to the development of a means to measure the quality of a cost estimate and a tool which would help novices to improve their learning curve, and experts to assess cost estimate(s).

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Educational, Social Aspects and Humanities Inside CE

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Transferring knowledge between implementers when building inter-organisational information systems

Raija HALONEN
Department of Information Processing Science, University of Oulu, B.O.Box 3000, FIN-90014 University of Oulu
email raija.halonen@oulu.fi
fax +358 8 5531890
tel. +358 40 5639 678

Abstract. Transferring knowledge is a real challenge especially when there are many independent organisations involved in developing an information system. This research tries to find out how the core challenge is met in this context. The research material is collected in a case where several universities were involved in implementing an information system to support student mobility between them. We concentrate on building interface between two information systems when distinct parties were on charge. The special nature of academia is emphasised in the research because there is no organisational command lines between different departments in universities. This character adds the need for interaction and communication in the project.

Keywords. Inter-organisational information system, knowledge transfer, development project

Introduction

Information technology (IT) enables interaction between people and organisations without need to physical attendance. Our case comes from academia where universities traditionally have developed their own way to manage. However, before this interaction is available, a lot of actions need to be managed. This paper explores the problems of managing knowledge transfer between organisations and actors when there are several independent organisations involved in implementing a joint inter-organisational information system (IOS). Our case showed that transferring information is not a natural consequence even in one university, without mentioning distinct organisations. On the contrary, it must be planned and taken care in time.

The research material is gathered from a case study where different information systems were to be connected in order to transfer information between each other. The goal was an IOS to support the management of student mobility between universities. Student mobility happens when students perform studies elsewhere as a part of their academic degree. The used research methods are case study and action research and they are highly subjective and interpretive. The empiric material is gathered from memorandums and a personal diary written by the researcher. In addition, emails and

phone calls were used. In this research the target organisations include an IT department of a university and a vendor organisation that implemented the information system. On top of them, there were other organisations involved in the collaboration.

This paper considers implementing information systems as Laudon and Laudon [1] defined it: "All organisational activities working toward the adoption, management, and reutilisation of an innovation". Implementing information systems has been recognised to be a challenge as itself [2,3] but implementing IOSs increases this challenge.

1. Problem setting and theoretical background

Implementing information systems has been a challenge for decades [e.g. 3,4,5]. Lorenzi and Riley [6] list reasons for failures when implementing information systems: communication, underestimation of complexity, scope creep, organisation, technology and leadership issues. Furthermore, co-operation is always a challenge when there are people involved [7,8]. Gefen and Ridings [9] note that users and IT developers often belong to different organisational units with different objectives and values. This issue is emphasised when implementing IOSs [10]. Our case comes from academia, proving notes of Hearn [11]: "universities represent a special environment".

IOSs differ from internal or distributed information systems by allowing information to be sent across organisational borders [12]. The relationship between the co-operating organisations and the coordination and co-operation between them is not as tightly coupled by structural authority as in vertically integrated hierarchies [13]. Williams [14] states that cooperation between the involving organisations is essential to the further development of IOS.

Challenges of information technology implementations have also been studied in cases when organisations are distributed [15]. Munkvold lists the main challenges as initiation of the implementation process, decentralised adoption, establishing connectivity, individual acceptance and establishing collaborative work practices. However, the cases of Munkvold consisted of one organisation.

Ciborra and Andreu [16] believe that managing knowledge differs in different organisational contexts. Ciborra and Andreu introduce a concept of 'learning ladder', meaning that two or more firms adopt a co-operative strategy and engage in some form of alliance. These firms share related knowledge management policies. The authors continue that in learning community, learning takes place through the practice of membership and it is hard to locate the know-how precisely.

Loebbecke et al. [17] suggest that transferring management should consist of:

- close interaction in inter-organisational collaborative teams
- managing dual commitment by rotating members of inter-organisational teams
- structuring intraorganisational knowledge teams.

Loebbecke et al. [17] conclude that IOSs developers will find a challenge to design and implement appropriate infrastructures and applications to support value-orientated inter-organisational knowledge sharing in the context of co-opetition, i.e. co-operating and competing at the same time.

2. Research methods

This study is qualitative and both action research and case study have been used in the research. The researcher was acting as a project manager in the IS project and thus she was able to influence on the goings in the project [18]. Her conscious chosen role was that of an involved researcher instead of an outside observer [19]. Schön [20] points out that action research is applicable in different environments. Action research is characterised by 1) its multivariate social setting, 2) its highly interpretive assumptions about observation, 3) intervention by the researcher, 4) participatory observation and 5) the study of change in the social setting [21].

A case study is an empirical inquiry that studies a contemporary phenomenon within its real-life context, especially when the borders between phenomenon and context are not clearly evident [22]. In addition, this case is described in detail enough in order to provide a thorough understanding of the diversified environment with several types of project stakeholders [23].

The researcher is interpreting the case when writing it down [24] and the approach is linked with the experiences of the researcher. The purpose of personal notes is to facilitate the research process through recording observations, thoughts and questions when they are used by the researcher [25]. In addition, the researchers will be interpreting the evidence when describing the complexity of human sense-making during the IS project [26].

The research material is collected from memorandums, 'short minutes' from meetings and encounters and from the personal observations made by the researcher. The researcher has written a personal diary [18,27] when working as a project manager in the implementation project. In addition, the emails and phone calls are used in the research. Furthermore, several seminars were held to inform the future users and IT responsibles in the universities and some material is gathered during those seminars.

"Best practice" [26] is used in data gathering, analysis and reporting. However, because the approach is highly subjective, the empiric part of the article has been assessed by a third party representing the IT responsibles in the universities.

3. Research findings

Our empiric material comes from an implementation project where an IOS called MoSu (Mobility Support) was designed and taken into piloting use by three universities. MoSu was to support student affairs officials when they managed student mobility in their universities. They supported their students' rights to study, they granted other students' rights to study and they gave statements and asked for additional information by using MoSu. They also invoiced the studies according to the information found in MoSu. Prior MoSu, all these manoeuvres had needed a lot of manual checking and lasted for days or weeks. In addition, the greatest user group consisted of students who applied for rights to study elsewhere. Outside of the project the IS was to be taken into nation-wide use after the piloting phase.

In the MoSu project there were several independent organisations involved. There were three universities (Uni_A, Uni_B, Uni_G) that piloted MoSu in the first phase. Traditionally the universities are autonomous and they follow their own procedures in managing their functions. In our case we had student affairs offices involved taking care of the issues connected with the student rights. On top of that, there were

departments caring for user authentication and database issues, added with people managing interfaces between their internal information systems and MoSu. In our case we used Shibboleth [28] as the authentication middleware. The given method appeared to be difficult to be set up and it was not specified for this kind of IS. Shibboleth was finally implemented between Uni_A and MoSu and required information from the databases in the Uni-A was transferred to MoSu. Shibboleth between Uni_B and MoSu passed only identification information but no study information and Shibboleth was not implemented between Uni_G and MoSu. Because of the independent nature of academia [29], the steering group of MoSu had no ways to hurry the EDP offices when preparing their readiness for that (Short minutes August 30, 2004).

In the beginning all the piloting universities used a same student record system (called StuRec in this paper). Because MoSu was aimed to be nation-wide in the future, also universities using a differing student record system were noticed by a fourth university. Furthermore, the project management was taken care in a fifth university. More complexity came with a virtual university VU that assured the nation-wide nature of the IS. In addition, the Ministry of Education was paying for the implementation and there were two vendors involved in the project.

However, a university is not a homogeneous organisation. We could see that even if information flew between the departments of student affairs of universities, it did not necessarily flow between EDP offices and the student affairs offices in universities. Diary May 4, 2005: "*He asked Tom if the Uni_G needs help in setting Shibboleth up. Tom didn't know. He didn't know about the tasks done with Shibboleth.*"

In addition, transferring knowledge between the MoSu project and the developers of StuRec was found problematic even if StuRec was represented in the project. "*We [in StuRec] have decided to build interfaces in StuRec to enable information retrieval about student records from different systems like MoSu.*" (Memorandum May 4, 2005). Still, when the MoSu project proceeded and it was time to realise interfaces between MoSu and student record systems in order to transfer information about passed studies a serious discussion arose. The project manager wrote her diary on 25 October, 2005: "*We had Tim from StuRec visiting in the meeting and he surprisingly gave a speech about how the interactions should be managed with control instead of ad hoc and how StuRec or Uni_A does not like that different stakeholders intervene in their systems. I answered that there has been a 'StuRec person' in the project group from the very beginning and that information have been available ever since. It only should have passed forward in StuRec.*"

Arranging seminars was found fruitful and necessary in order to get right people in contact. The first MoSu Seminar was held in December 16, 2004 and it was targeted to student affairs officials around the country. The goal of the seminar was to deliver information about the forthcoming IS that would be available to every university in the country. The discussions were active and information was delivered to people coming from different universities and their student affairs offices. (Summary from the seminar).

Furthermore, there were small meetings addressed to people connected with building Shibboleth in the Uni_A. These meetings were called by the party that was acting as a Shibboleth operator. The first meeting concluded that in January 2005 the constant values in Shibboleth will be replaced with real data as soon as connection between Shibboleth and StuRec was built. In addition, it was agreed that this kind of meeting is needed also during the coming months. (Short minutes December 16, 2004).

The second meeting for the ‘Shibboleth people’ was arranged in April 2005. The Uni_B was represented and the situation of Shibboleth readiness in the Uni_B was described. For the time being, Shibboleth was not fully installed and there were still problems with audits and security certificates. In addition, only few attributes were solved between Shibboleth and StuRec. (Short minutes April 4, 2005).

In the Uni_A there was a whole team that managed issues related with Shibboleth and MoSu. However, it was not enough that the Uni_A team knew what to do and when. When developing the IS and interfaces there, information had to be forwarded in time and to right people. Furthermore, StuRec was the master student register system and it was carefully secured from MoSu. In addition, there was the operator who was responsible for the agreements when transferring information across organisational borders. The developer of MoSu had only limited rights to the MoSu server and no rights to the Shibboleth server of the Uni_A. Therefore the information about done actions had to be delivered him frequently.

Finally in spring 2005 a mailing list was set up by the EDP team in the Uni_A and information was to be delivered using this list. In addition, the team in the Uni_A kept a diary where they described the tasks and procedures that had to be catered before Shibboleth was set up. In addition to helping people in the first Shibboleth implementation, the mailing list and the diary were to help other EDP offices with their Shibboleth.

Several components in the MoSu palette were moving simultaneously. The developers found it difficult to code the IS and its interfaces when Shibboleth was being modified in the other end. On several occasions knowledge was not available when it was needed. "*I'm sorry about this outburst but we really don't know anything about this task and this 'cgi' is everything we have been told even if we wanted to know more about it!*" (Email August 8, 2005).

The second seminar aimed for responsible of student record systems and their developers was held in August 22, 2005. The target group included also people from the EDP offices, especially concentrating on people who would be responsible in building Shibboleth to be used with MoSu. The seminar was very informative and it realised the need of transferring knowledge between different development groups. One session handled the Shibboleth implementation that had been carried in order to enable MoSu to use information from the university’s information systems. Even if Shibboleth already was in use in the Uni_A, it needed a lot of issues to be managed before it was in use with MoSu. Uni_A was acting as a service provider when the other universities only had to build their identity providers. So far Shibboleth had passed information about user’s email address between the university and another IS (e.g. library IS). MoSu needed about 40 attributes to be specified in Shibboleth. The transferable information was to be fetched from the LDAP repository and StuRec of the Uni_A.

One designer of the Uni_A gave a presentation in the seminar where he summarised the typical problems when building Shibboleth to be used with MoSu:

Typical problems in distributed software development (as MoSu was and still is):

- *testing environments were not in line with each other*
- *many different stakeholders – co-operation was lacking*
- *documentation was lacking – technical changes came first*
- *bureaucracy – the information was forwarded using contact persons*

However, he was able to list some positive comments as well:

– *Shibboleth technology is functioning and still improving*
– *aimed functionality was achieved with Shibboleth.*

The project manager learnt that it is not enough that the project personnel consists of people from participating universities and that it is not axiomatic that the information flows between departments in the university. This is the case especially when they do not come from all the appropriate departments (Diary August 22, 2005).

It appeared that Shibboleth was far from ready to be used as it was required when transferring information to be used in MoSu. The FunetEduPerson Schema (Shibboleth, 2005) was under development. The IT people in the Uni_A wanted to keep in the official schema: "*Apparently in the forthcoming versions of FunetEduPerson they change into another format but it isn't settled yet. Here in Uni_A we try to follow the FunetEduPerson Schema when it is updated.*" (Email September 14, 2005).

The mailing list was very useful also when transferring information about the missing attributes and faulty formats there. However, because of the remote nature of the mailing list, it did not reach appropriate people immediately. This was felt unpleasant because of the tight schedule of MoSu and because there was no means to figure it out if anybody had seen the messages. "*I haven't got any answer and I do greatly wonder the silence. Are there new problems to be found or what?*" (Email December 18, 2005).

4. Discussion

The aim of the IOS was to support the student affairs officials when they managed student mobility in their universities, and to enable students to apply for rights to study using electronic system. Student mobility happens when students perform studies in other universities as a part of their academic degrees.

Our case comes from the academia where several universities were involved in designing and implementing a joint IS to support their management of student mobility. Our empiric case was an example of a diversified implementation project where stakeholders changed over time and where the need of strong interaction was emphasised. Despite that, there were problems with transferring information between different stakeholders and organisations. The developers felt frustrated when they were not informed as they wanted (Emails August 2005). They felt that knowledge about Shibboleth was hidden from them (private call), giving advantage to another party in the MoSu project [c.f. 17]. In addition, the IT people in the Shibboleth team did not always know where to get the needed information.

The role of Shibboleth is emphasised in this study because its role was to act as a gateway or gatekeeper between universities and MoSu when fully implemented. In this sense, implementing Shibboleth appeared to be an effort that was not overtaken by all participating universities. On top of that, many of the problems with transferring information between implementers culminated with Shibboleth because the technology was new and there were several implementers involved, representing different organisations.

As Hearn [11] notes, academic organisations are independent and they are used to take care for their own functions. In addition, universities consist of several departments that attend to their own functions, respectively [29]. There is no linear command power between departments – meaning that e.g. student affairs offices were not able to push EDP offices to improve user administration or to set up a diversified

authentication middleware because they needed it. Lack of communication was realised between student affairs and the Shibboleth team when compulsory fields in the application form were not found in any master information systems. "*We got an impossible requirement. The number of study credits in major subject was required in the application form but it's impossible to produce that number from StuRec in the Uni_A*." (Seminar August 22, 2005).

The MoSu project arranged seminars to spread information about it. It seemed that this was the only way to give advance information about its features and schedule to the universities and their EDP offices and student affairs offices. The target group was unaddressed because nobody knew who were responsible for the many issues related with MoSu, user administration and Shibboleth in the several universities. In addition, MoSu was on view in a nation-wide seminar arranged by EDP leaders in the country, but there was no big interest in it.

The mailing list appeared to be a good tool to transfer information between people in different organisations. In addition to spreading information between the developer and the Uni_A, it transferred knowledge between people in the EDP office in the Uni_A. Setting Shibboleth to be usable with MoSu was not the main function in the EDP office but a minor detail that had to be carried out. However, the EDP office gained a lot when setting Shibboleth because the role of Shibboleth was growing in the university.

In addition to the mailing list, the conventional email was in active use. The emails were sent between persons, aiming to reach the right person and not to bothering all people in the mailing list. However, it happened that occasionally the list of receivers grew and many times they were the same people than in the mailing list. Furthermore, often also the nature of the messages was more personal because the sender was aware that the aimed person got the message.

In our research the problem of communication was evident especially in the project group in cases when information did not flow outside of the project group even if the members represented their organisations and they were nominated as contact persons in their university. Underestimation of complexity was realised when modifying Shibboleth to be usable with MoSu. Nobody had any idea about the work load that it inflicted. Shibboleth and interfaces related with it can be connected also with the problem of technology. Finally, also leadership issues were occasionally found problematic especially when there were conflicts with the VU and its goals with the project, not to forget the prevailing problem with sharing knowledge.

In our research there was no problematic relations found between the user-organisations. Despite the identified obstacles described by Lorenzi and Riley [6], there was no fear of abandoning the IS by the users. Both the student affairs officials and students were mostly very satisfied with MoSu according to the feedback they gave. "*The electronic application form was excellent! The instructions were well planned and informative. Once for all – a really user-friendly experience*." (Feedback May 17, 2005). "*Well done and a handy service!*" (Feedback June 1, 2005). "*This is really much better way than filling papers and sending them to several places. Thanks!*" (Feedback July 7, 2005). The student affairs officials expressed their opinion by stating that they want to continue with MoSu even if the piloting will be over (Short minutes May 9, 2005).

The principles introduced by Klein and Myers [26] have been in the background when carrying out this research. Hermeneutic circle is concerned when trying to understand the relationships between project stakeholders in the context of the project

organisation. Interaction between researchers and subjects has been live in project meetings and encounters. Noticing the importance of transferring information and knowledge between needed departments in organisations and between organisations can be generalised to concern other IOS projects. Multiple interpretations are realised in this research by using both project documentation and the personal diary written by the project manager when interpreting goings. In addition, the empiric results were evaluated by IT people who were connected with building Shibboleth and related things but who didn't belong to the MoSu project themselves. The principle of suspicion leads us to evaluate the diary of the project manager and the short minutes that are written from meetings and encounters.

As a conclusion - seminars, the mailing list and emails were the most important tools that were used in our diversified implementation project when knowledge was transferred between independent stakeholders. Despite their unsophisticated nature, they were the keys that solved the problems in communication.

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Leading the Web in Concurrent Engineering
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CE in Engineering Education: An Observation from the Experience

Teruaki Ito
Institute of Technology and Science
University of Tokushima
Tokushima 770-8506
Japan
E-mail: ito@me.tokushima-u.ac.jp

Abstract. Concurrent Engineering is one of the key issues of manufacturing to be competitive in the global market place. Even though the major goal of CE would be to reduce the production lead time and to increase of quality of products, its basic idea includes several important engineering elements, such as the clear goal setting, the effective communication strategy in team working, or the problem solving approaches to apply to real problems, which should be taught in engineering education. Reviewing the two examples of engineering education classes from two different institutions, where the author has been involved as a teaching staff, this paper discusses the major factors of success in these classes. This paper shows how these important elements of CE are taught in these classes, and clarifies why the success of these classes has been made.

Keywords. Concurrent Engineering, distant learning and teaching, collaboration tool, network communication, engineering education

1. Introduction

Concurrent Engineering (CE) [1] is regarded as one of the key issues of Product Realization Process (PRP) to be competitive in this global market place. To support the concurrent engineering, CE methods and supporting tools have been reported and their feasibilities are reported from industries. To decrease the production lead time is one of the key issues in CE, but CE also pursues to increase the quality of product. CE is closely related to product developments, but its basic idea includes various important elements which could be applied in many application areas. These key elements of PRP include teams/teamwork, communication, design for manufacturing, CAD systems, professional ethics, creative thinking, design for performance, design for reliability, design for cost, drawing, reliability, value engineering, and design reviews. Therefore, the basic idea of CE could be an interesting educational subject which should be taught in engineering classes. One approach to teach these subjects might give a lecture in a teaching class. Another approach could be to teach the students how to use these basic ideas of CE in engineering exercises, which will be addressed by this paper.

First, this paper addresses the critical issues in engineering education, which is how to teach creativity in engineering. Just as many other engineering classes, the two examples of teaching classes presented in this paper have been taking strenuous efforts to tackle this issue. One example is 2.007 [2] from Massachusetts Institute of Technology (MIT), and another example is CAD-EX [3] from the University of Tokushima (UT). Although the contests and histories of these classes are very different, both of these classes have been highly evaluated by the students who took the classes so far. Both of these classes do not explicitly mention the term of CE in their syllabus. However, the basic elements are introduced and applied in each class, which could be one of the major factors to make the classes a great success. Based on the observation over these classes, the last section discusses the advantages and drawbacks of these classes, and clarifies how CE works in engineering education.

2. Engineering Classes and CE

Creativity in education has been regarded as a very important goal not only for students but also for faculty, and various approaches have been reported. This section first shows some of these approaches to teaching creativity in Engineering Education. The two classes presented in this section are the other good examples which focus on the creativity education. One example is 2.007 from MIT and another example is CAD-EX from UT. The author has spent a research leave at MIT in 2005-2006 under the advanced education program of the Ministry of Education in Japan. The 2.007 example is picked up because the author has attended all of the class works in 2005 and has a good understanding about the class. The CAD-EX example is picked up because the author is in the charge of the class.

2.1 Engineering Education focuses on creative education

A. Hands-on education

The Education Consortium for Product Development Leadership in the 21 st Century (PD21) developed a design challenge in product development [4]. The hands-on approach highly integrated with the studio approach [5][6] has been reported with good success. As an innovative approach to providing physical demonstrations in the engineering classroom, a haptic paddle was introduced and achieved great success. [7][8].

B. Teamwork-based learning

Building courses on the technical information and concepts developed in introductory required courses, and adding reality to the design process by using engineering teams, student's motivation within laboratory courses increased significantly [9].

C. Project-based learning

Design is widely considered to be the central or distinguished activity of engineering [10]. It is also said that the purpose of engineering education is to graduate

engineers who can design effective solutions to meet social needs [11]. "Appropriate design" courses appear to improve retention, student satisfaction, diversity, and student learning [12].

D. WWW-based lectures

WWW-based teaching is pertinent to both local and distance education, and literature studying the efficiency of the WWW in distance education is supportive of the premise that WWW-based lecture can be very effective [13][14].

2.2 Example 1: Design and production class - 2.007 –

Creative education is one of the major goals for these examples presented in this section and the next section. The design and production class at MIT (2.007) teaches a creative design process, based on the scientific methods, with lectures and the creation, engineering, and manufacturing of a remote controlled [15] mechanical machine to compete in a major design contest at the end of the semester. Students learn to identify a problem and create, develop, and select best strategies, and concepts using the fundamental principles, appropriate analysis, and experimentation. The students then divide their best concept into modules and after developing the most critical modules first in descending orders of criticality, proceed to system integration, testing, and debugging. The physics and application of machine elements to enable students to create and engineer their machines are introduced by lectures and examples. Throughout the course, engineers' professional responsibilities are stressed. Students are assumed to be competent at parametric solid modeling, spreadsheets or MatLab, and basic machine shop skills. Educational, reference, and design assistance materials are provided on-line to enable students to learn as much as they want/need whenever they want/need.

As a part of OCW project [16], the 2.007 web site provide almost all of the teaching materials and class information to the public. For example, the course syllabus, the lecture notes and slides, the contest rules and regulations, the contest results in the past as well as in the current year, the kit material information including the solid models for CAD modeling, various software programs to be used in the design of robots, the administrative information, etc. The students' grades information is not on this web site, but is handled in the secured MIT site which is only accessible to the authorized users.

2.3 Example 2: CAD-EX class

The CAD-EX class at UT teaches the students how to design solid models on a teamwork-based approach [3]. The student teams work together to build solid models in a reverse engineering way using commercial plastic toy models. The final goal of the assignment is to accurately build the solid model which is identical to the corresponding plastic model. During this teamwork, the students not only learn how to use the solid modeling software, but also learn how to work in teams, to manage time budget in their projects, to regenerate the accurate solid models, to make peer-review, to give the good presentation, etc.

The CAD-EX web site is currently only available for the inside of the campus network of UT, but effectively works for the class. For example, the lecture notes, the

instructions, the template files, are distributed to the students by the web server. In addition to this distribution role, the web server has a collecting role, to collect the homework paper, the reports, the presentation materials, the solid models, etc.

3. Observation from the Experience

Each of these two classes described in the previous section was reviewed and highly evaluated by the students who took the classes. Even though both classes do not mention the term of concurrent engineering in their syllabus, the contents include the very important elements of CE. As a result, the students understand the importance of CE and how to apply them to the engineering exercises, which makes these classes a great success. This section picks up some of these elements.

3.1 Effective use of the web-based tools

The use of web-based tool shows effective impacts and outcomes in both cases even though the contests and histories of these systems are very different. The web site of 2007 was renovated a few years ago to keep the consistency in the past contents covering the many years of its history, which was achieved by the strenuous efforts of the staff member. This web site is operated independently from the OCW sites. Meanwhile, the web site of CAD-EX was setup at two years ago to support the teamwork-based class work, which is also by the strenuous efforts of the staff member. In both cases, the system is not intended to provide the distance learning or distance teaching to the remote participants, but rather to provide the effective mean of information sharing among the participating members of the classes. Just like the integrated CAD system is the core of PRP, these web-based tools works as a core system in these classes.

3.2 Clear goal

Just as the goal of PRP should be clear, the goal of these classes is very clear. The students know what they should do in the class and what they are supposed to achieve in the end. In 2.007, the goal is to win the competition. What the students should do is to design and build a machine which could win the competition. The students are not given the design specification, but they must design the specification to win the competition. In CAD-EX, the goal is to build the digital 3D model, which is exactly identical to its original physical model. The students know what they should build because the physical model is just in front of them. The students must learn how to use solid modeling software to build the digital model. The clear goal gives the great direction to the students to achieve the goal in the most effective way, which is very similar in PRP which produces the competitive product.

3.3 Clear schedule and time budget

The schedule and time budget are very important factors in CE. The class work is a good example of how to manage time budget. In 15 weeks, the students are required to manage the schedule so that they should achieve the best results in the limited time

budget. In both 2.007 and CAD-EX, the final week is the due date when the students should present what they build. To meet the due date, the students are required to obtain the skill of scheduling by which they could perform the best results. Without the clear schedule of design and production at the early stage of the class work, they cannot meet the due date with the good results. The students could learn the important meaning of the time budget.

3.4 Considering financial and other budgets

Design for cost is one of the critical issues which design engineers deal with in PRP. In the same way, the financial budge is an important thing what the students should learn in the class. The budge for parts and materials is limited and should be used in the most effective way. In 2.007, one set of kits are given to each students. The kit includes all of the parts and components which the students can use in the class. The students learn the idea of trade-off in design and production. In CAD-EX, the target model is determined by the group, considering the difficulty of modeling and the number of components, as well as the price for the plastic toy model. Even though the physical production of the model is not required in CAD-EX, the students learn many aspects of design in team-work, including role playing and collaborative work.

3.5 Simulation and production

The simulation and production are both important in PRP. The students could just build a machine without the detailed calculation or simulation. However, the theory plays a very important role not only in design and production, but also in discussion and reviews. In 2.007, the students are given the chances to carry out the simulation regarding the machine which the students are going to build. In CAD-EX, the physical production is not required to the students because of the limitation of the class work time. However, a rapid prototyping assignment was given to the best scored group as an extracurricular activity. As a result, the students of the group enjoyed the activity and built a very nice rapid prototype model. For the future work, an assignment of physical modeling is under consideration in CAD-EX.

3.6 Team-working

The students work in team. As for the 2.007, each student design and build a machine independently, which may seem to be a non-team working activity. However, it is a team working activity because the peer review is always active throughout the class [17]. In addition to that, the students interact not only with the peer reviewer of the students but also with the instructors, advisors, technical staffs, parents, guests, and many more. The team-working is a great help on what the students design and build the machine. As for the CAD-EX, the students work in team which is composed of around six students in each team. In each team, the students are supposed to play their own roles including, the team leader, the modeling master, and other roles. The students take the responsibility in the assigned role in the group and work collaboratively to achieve the goal in the due time. These team-workings observed in the classes are exactly what the CE team is required to learn and practice.

3.7 Communication

Communication plays an important role in team-working. In addition to the conventional face-to-face communication, the web-based tools used in these classes provide an innovative environment for communication in team-working. What the students can share in this communication is not only the information and idea, but also digital data in various categories, which could also be shared with the teaching staffs for review, discussion, suggestion, and evaluation. Good communication is the key to PRP. If the security issue could be handled properly, the global team working would also be possible in these classes.

4. Discussions

The two examples of engineering education presented in this paper provided several interesting topics of discussions. This section discusses some of these topics.

4.1 Security

The web-based tool to support the class like the 2.007 and the CAD-EX is required to be always kept stable and secure. It should be open to all of the associated users but should be closed to the general public. The system could be maintained secure and stable by the special person or some special organizations, even though it would not be achieved easily. However, if the system is maintained by the users themselves just like in the case of CAD-EX, it may have to be closed in the campus network to make it secure. This security issue includes various open issues to be solved, which may be the same as those systems in PRP.

4.2 Motivation

One of the most critical issues in engineering class would be the motivation to learn. This is what the teacher should give to the students in the most effective way, and this is what the students expect from the class substantially. If the motivation is clear and understandable to the students, the students would do their best in any way even if they are not told to do so by somebody, or even if the learning materials are not available enough. The students would find a way, which would be quite often observed in the hobby world. However, this is an open question and it is not easy to give the good motivation to the students in a class room. The robot competition and the final presentation shown in the two engineering class is this paper are the good example to give the good motivation to the students. Many more rooms for discussion and consideration remain in this issue.

4.3 Friendly and healthy competition

According to the experience from these classes, the class work should be a fun activity which not only the students can enjoy but also the teaching staff can also do so in order to get the best results. Therefore, it would not be the task pursued only the faculty members. A great idea could only be generated from the interaction and

collaboration between the faculty members and the students, because the idea should be attractive to both of them. A friendly and healthy competition will surely make the class fun, which was recognized from the experience from both 2.007 and CAD-EX classes. The competition in the real world is not always fun, but that of the class should always be fun to all of the participating members. The students should be competitive each other in order to learn many important lessons from that [18].

4.4 Collaborative activity

Education is an interaction between the faculty members and the students. However, it could make it much more fun and productive it the interaction expands and includes many more people who would support the education. This is what is happening in these classes with successful results. The idea of robot competition expands the class work to the general public and provides an opportunity to invite people from outside of the class, which include other faculty members, former students, sponsor people, parents of the students, etc. To make the involvement of these people effective, the class work and the system must be tuned to comply with the voice of them. Some of the important elements of CE would be the key.

5. Concluding Remarks

This paper described an observation from the experience in the two types of engineering classes regarding CE. The area of CE is very broad and may not be covered in engineering classes. However, some of the important elements of CE are very powerful tools not only in product development fields but also in general areas. Therefore, these important elements could be very interesting topics in education. One approach might be a lecture in a class room but another approach could be a manufacturing class in engineering education. The two examples of these classes presented in this paper shows how these elements of CE could be taught in engineering education, and how effectively be used in the class activities. The author hopes that this paper could give some tips for those people who are thinking about the introduction of CE in engineering education.

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Adapting the ELO rating system to competing subpopulations in a "man-hill"

Grégory Valigiani [a,b] Evelyne Lutton [b] Pierre Collet [a]
[a] *LIL Lab - ULCO - 62228 Calais - France*
[b] *COMPLEX Team - INRIA Rocquencourt - 78150 Le Chesnay - France*

Abstract. Paraschool (the French leading e-learning company, with more than 250,000 registered students), wanted an intelligent software to guide students in their graph of pedagogic items. The very large number of students suggested to use students as artificial ants, leaving stigmergic information on the web-site graph to optimise pedagogical paths. The differences between artificial ants and students led to describe a new concurrent paradigm called "man-hill optimization," where optimization emerges from the behaviour of humans exploring a web site.

At this stage, the need of rating pedagogical items showed up in order to direct students towards items adapted to their level. A solution was found in the ELO [12] automatic rating process, that also provides (as a side-effect) a powerful audit system that can track syntactic and semantic problems in exercises. For an effective use, this paper shows how the ELO rating process has been modified to overcome the Deflation problem.

Keywords. E-Learning, Ant Colony Optimization, "Man-Hill" Optimization, concurrent optimization, ELO Rating, Turnover, Sub-pools.

Introduction

Paraschool is currently the French leading e-learning company, with more than 250,000 registered students. Back in 2002, Paraschool was looking for a system that could enhance web-site navigation by making it intelligent and adaptive to the user. Since the tree of available excercises could be turned into a graph visited by students (where pedagogical items are nodes and hypertext links are arcs), Ant Colony Optimization (ACO) techniques (a concurrent optimization paradigm [4,1,2]) could apply and show interesting properties: adaptability and robustness.

Unfortunately, real-size experimentations have shown that ant-hill optimization techniques developed in Paraschool do not directly apply because students do not behave like artificial ants. The concept of an artificial "student-hill," or more generally "man-hill," has been introduced and analysed [7,8,9].

In a refinement stage[10], the level of items and students needs to be evaluated in order to direct students towards exercises of matching level (there is no point in suggesting an exercise that is overly difficult or simple to a particular student). The Paraschool pedagogical team could rate the different items based on their

knowledge and experience, but what may seem simple for a teacher may seem difficult for a student. Moreover the level of the students must also be evaluated, which is quite difficult if the student does not have a long enough interaction with a human teacher.

A solution to this very important problem was found in the chess world, with the automatic ELO rating computation. After a short description of the Paraschool "man-hill" concurrent optimizer, the chess ELO rating is described in section 2 and then applied to Paraschool system in section 3. Results over 4 years of data show that the ELO evaluation process can be modified to overcome the known problems of the ELO system, thanks to the specificities of the e-learning system.

1. The Paraschool "man-hill"

1.1. Ant Colony Optimization

The Paraschool e-learning software is used in French schools or by individual students at home over the Internet. Connected students have access to thousands of pedagogic items (know-hows, lessons, drills) that were originally deterministically related by hypertext links.

The aim of the presented work is twofold:

1. find the best succession of items to maximize learning, and
2. insert some intelligence into the system so that different students have a different view of the Paraschool software.

ACO (developed after the observation of ant-hills [6,3]) uses virtual ants to find minimal paths in a graph. In the Paraschool system, the very large number of students triggered the idea to apply a similar technique using real students rather than virtual ants, with the aim of optimizing pedagogical paths traversing a set of educational topics. Students release artificial pheromones on the graph, depending on how they validated an item (success or failure). This stigmergic information can then be used by other students to choose their way on the different possible pedagogical paths.

Developing an ant colony optimization technique using human students on the Paraschool graph has however led to the (obvious) conclusion that humans do not behave as natural or artificial ants:

- There is no control on human students as on artificial ants.
- Artificial ants are permanently active on the entire environment, to the contrary of students (holidays, navigation per topics along the year).
- Social insects are inherently altruistic, while human users are individual by essence: they do not like to be treated identically, and on the contrary, appreciate systems that are adapted to their particular case.

Tests have shown that because of these differences, the standard ACO paradigm does not work straight out of the box. The concept of "man-hill" optimization has therefore been introduced. Problematic pheromone evaporation dur-

ing periods of inactivity over some areas of the graph has been solved by a new concept of pheromone *erosion*, and the need for individuality is dealt with thanks to the introduction of *multiplicative pheromones*, that only belong to a particular student. A further refinement allowing to tailor the system for a specific student is to take into account the level of the student, and direct him toward exercises he has a reasonable chance to solve. In order to achieve this, one must find a way to rate the drills and the students.

2. Using an ELO rating scheme in an interactive tutoring system

One could think of several ways to rate the respective difficulty of a drill and the proficiency of a student. The first idea that comes to mind is to ask the teachers who wrote the items to rate them on a scale going from easy to difficult. An experiment over 45 items has been done with two different teachers who were asked to evaluate items on a scale from 1 to 6. It appears that 8 evaluations did not reflect the real success rate of students on the item and 16 other evaluations were not quite right. This method tends to be error-prone because it relies on the judgment of the teacher, and on the level of the student that is faced with the drill. A much better system would be an automatic rating process for both items and students, but such a thing is very difficult to calibrate. The chosen solution was to use a very refined system called the ELO rating [12], that has been used in the Chess community for the last 50 years, where individuals compete against each other on a regular basis. At the end of the fifties, a mathematician, A. E. ELO [12], developed a chess rating system, based on the Thursone Case V Model [11] which has been adopted by chess federations worldwide. The ELO system was successful, due to the fact that rating differences between two competitors $(s_i - s_j)$ and mutual winning chances are much more clearly related in this system than in any other. Moreover, ELO was the first to use computers for his calculations, which enabled him to rate a huge amount of players.

2.1. Rating update

The equation $S_i(t+1) = S_i(t) + K(R_{ij} - R_{ij_e})$ describes how an original rating $S_i(t)$ is updated as a function of the expected outcome R_{ij_e}. If i and j are rated players, one can logically expect the stronger to win over the weaker. The expected outcome is called R_{ij_e}. However, the real outcome of the game R_{ij} may be different.

If $R_{ij} = R_{ij_e}$, the rating of the players was accurate. If $R_{ij} \neq R_{ij_e}$, the ratings $S_i(t)$ and $S_j(t)$ need to be updated to reflect the outcome of the game.

The impact of the $R_{ij} - R_{ij_e}$ difference is tuned thanks to a variable K, which represents the maximum amount of points that can be won in one game. A high K-factor gives more weight to new results while a low value increases the influence of earlier performances. The K-factor fluctuates between 16 for great players (ELO-rate$>$ 2400) and 32 for weak ones (ELO-rate$<$ 2100).

According to the Bradley-Terry Model[11], if the rating difference $(S_i(t) - S_j(t))$ is known between players i and j, the expected probability of success of player i against player j can be defined as:

$$R_{ij_e} = \frac{1}{1 + 10^{\frac{S_i(t) - S_j(t)}{400}}}$$

This is the basic formula for the rating system of the United States Chess Federation.

In the Paraschool system, one can consider that students and exercises "compete" against each other, with the nice outcome that one can objectively compute their respective ELO rating, independently of any biases.

2.2. Inflation and Deflation

Since the introduction of the ELO rating system in the world of Chess, some problems arose because of:

Turnover : If no individuals enter or leave the pool of rated players, then every gain in rating by one player would (ideally) result in a decrease in rating by another player by equal amount. Thus, rating points would be conserved, and the average rating of all players would remain constant over time. But, typically, players who enter the rating pool are weaker than players who leave it. The net effect is this flow of players lowers the overall average rating.

Sub-pools : Inflation and deflation does not only occur in the rating pool as a whole but also within subpools. A subpool is a subset of players who keep playing together over longer periods of time without much contact with players outside their group. This results in subpools with artificially low or high ratings. Within the subpool, ratings may still have a reasonable predictive value, but as soon as players from a subpool enter larger tournaments, they will start winning/loosing many points quickly, until their ELO rating is readjusted with reference to the larger pool. Altogether, the subpool-phenomenon shows that it is important for players to periodically play against people outside of their sub-pool.

These factors question the "integrity" of the ELO system, as they can create a general inflation or deflation of the global ratings. The integrity of the system indicates to which extent a given rating s_i reflects a same level over time, and across different sub-pools.

3. ELO ratings inside the Paraschool System

Since the algorithm already works quite well in the chess environment, the same equations and parameters were used for Paraschool. As soon as a student rating has stabilized, applications are numerous:

1. Students have a way to know their level, and can visualize their evolution.
2. The Paraschool pedagogical team does not need to put a subjective artificial rating on each item.

3. A very interesting side effect is that the ELO rating can tell if a drill contains a semantic or pedagogic flaw (something very difficult to detect otherwise, when there are thousands of different items): if an item has an extremely high ELO rating, this shows that either there is an error in the exercise, making it impossible for students to solve it, or that the exercise is much too difficult for the students to solve (indicating a pedagogic flaw). The same goes for items with very low ELO values, that are either too simple for the students, or that can be solved using a bypass (not requiring the mental process planned by the teacher). The ELO rating of items revealed to be an invaluable aid to the Paraschool pedagogical team if considered as an audit system.
4. Finally (and that was the primary goal of the implementation of the ELO rating), the man-hill system can be refined to propose items adapted to the strength of a particular student.

3.1. Paraschool subpools

In Chess tournaments, any player can possibly compete with any other player, even though most competitions are held within specific countries.

In the Paraschool system, it is much less so for several reasons:

1. An item cannot compete against another item, and a student cannot compete against another student. This *de facto* creates two subpools, but of a different kind, where players can play exclusively with an individual of the other group. This peculiar dynamics is different from what occurs in the chess environment, and it can be used to find a way to get around the deflation problem (cf. below).
2. The Paraschool system also exhibits chess-like subpools, since it hosts students of different grades. After analysis, 95% of students in a grade exclusively compete with items of their grade. This leads to the conclusion that the student ELO rate may be inconsistent if a student tries to solve a problem of another grade. In this case, the decision was simply not to take into account a "match" between a student and an item of different grades. This means that 5% of information is lost, but the impact on the system is minor.

3.2. Turnover in Paraschool

As in Chess, turnover in Paraschool represents students entering or leaving the ELO rating system. These cases happen more often in the beginning/end of the school year. Normally a student should keep his account for several years. In practice, however, schools unfortunately update student lists and accounts every year, leading to possible turnover concerns.

On Fig. 1, the number of visits clearly shows periods of inactivity during summer vacations. In between, the average ELO rate of students tends to increase, which is a positive result (students are getting better). The drop in the beginning of each year comes from the fact that Paraschool increased its number of students

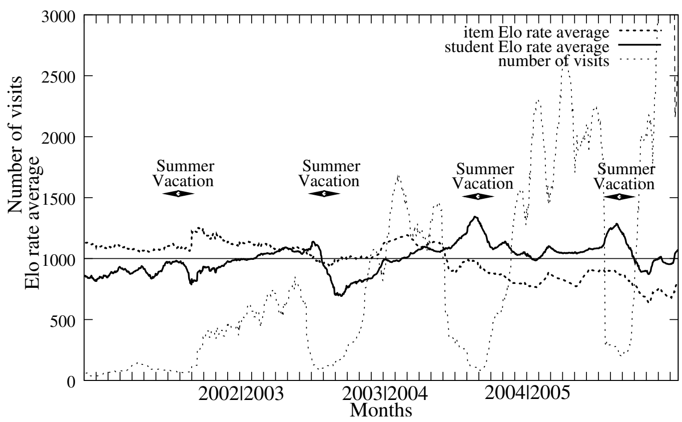

Figure 1. Average ELO Ratings and number of visits over a four years period.

from 50 000 to 250 000 over the four years on which data was collected (as can be seen by the increasing number of visits).

Fig. 1 also shows that the ELO rate of items tends to decrease year after year. This is because, to the contrary of schools (that reset student accounts every year), Paraschool does not reset the ELO rating of items, therefore causing a constant deflation of items ratings, as students get better over the years and steal ELO points to the items.

As seen above, the dynamics is different in the Paraschool system, since the system is dealing with two groups (the students and the items) that exclusively compete against each other. If one group has a stable ELO rating, this should stabilise the rating of the other group too.

The idea is then to apply different ratings for each group, in order to obtain greater stability and fight against natural deflation. For the students, the classical ELO rate system is kept. For the items, two options were studied:

Freezing: After a period of stabilization, the item gets its optimal rating and then deflation occurs. The goal is therefore to freeze the item before deflation begins. This means that once an item has its mature ELO rating, it keeps it forever, therefore stabilizing student ELO ratings at the same time. But the ELO rating of an item should also be computed from stabilized students.

Since the average number of visits per student (resp. item) is around 26 (resp 236), it was decided that student (resp. item) "maturity" would be obtained after 10 (resp. 75) evaluations.

On Fig. 2, the overall ELO gain is displayed depending on these two parameters: the number of evaluations after which an item is considered to have its optimal rating (*item_ maturity*), and the number of evaluations after which a student is considered to have his optimal rating (*student_ maturity*).

Probability-based ELO Rating for Items (PERI) If the classical ELO system can be seen as being too adaptive (therefore leading to deflation), the *freezing* method can be seen as being too static.

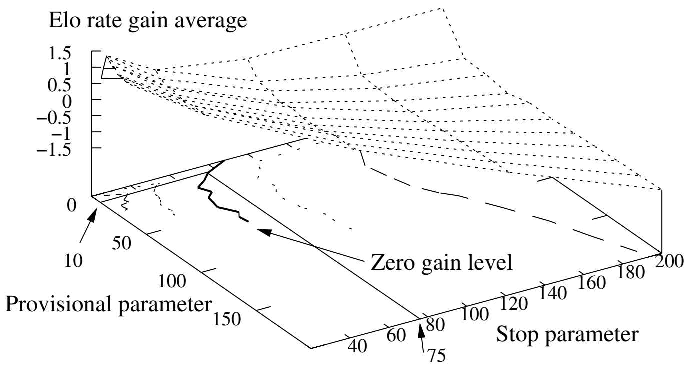

Figure 2. Average ELO gain over 4 years.

The ELO system is based on the fact that it is possible to compute a winning probability from the ELO ratings of two players. This means that if the winning probability of a player is known, one can evaluate his ELO rating by inverting the equation.
The PERI method computes a rating for items according to the success/failure ratio of students who tried to solve the item up to now. This means that the PERI rating is not subject to deflation, while at the same time, staying adaptive.

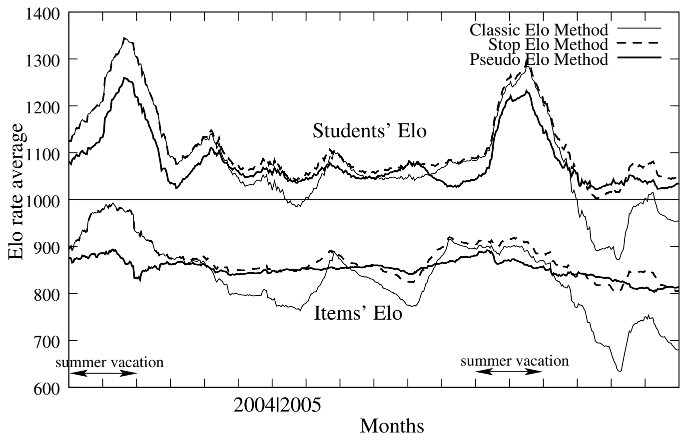

Figure 3. Average ELO Ratings for three ELO rating methods over a one year period.

Fig.3 shows the ELO rating of items and students during the previous school year (2004/2005) where the Paraschoom "man-hill" system should have found its stability. The thin solid curve represents the oscillating ELO rate of the standard method. The dashed curve shows the result of the *Freezing* method, while the bold curve represents the result of the PERI method. It appears that PERI is the most stable method over the year (with the *Freezing* method second, and the standard ELO rating third). It also appears that the students ELO rating (the

three upper curves) are oscillating with the three methods, but the range of the oscillations is smaller with the PERI method.

4. Conclusion

This paper introduces a new application for the ELO rating system, along with a new scheme allowing to prevent deflation of ELO points in the global system, as in the Paraschool concurrent "man-hill" system, it was possible to take advantage from the fact that one subpool was static (the items) to also stabilise the other subpool. By adding this automatic rating system, Paraschool hopes to get a good idea of the level of students and items, without the need for teacher evaluation.

This information can also be given to students, with two outcomes:

1. The students will get an idea of their proficiency, and will be able to follow their relative progression while using the system.
2. The E-learning system could observe the behaviour of each student when the possibility of choosing between a simple or a difficult item arises, and therefore get some indications on the pugnacity of the student, to even more specialise items suggestions (giving harder exercises to students who like difficulty, for instance).

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Towards Holistic Approach for Business Informatics – Oriented Skills Formation in the Knowledge Economy

Aurelian STĂNESCU[a,1], Ioan DUMITRACHE[1,a,2], Markus HELFERT[b,1], Howard DUNCAN[b,2], Adriana MIRCEA[c,1], Dan GÂRLAŞU[c,2], Mihnea MOISESCU[a,3]

[a] *University POLITEHNICA Bucharest; Automation and Computer Science Faculty*
[b] *Dublin City University, School of Computing*
[c] *Oracle - Romania*

Abstract. The author's goal within the present paper is to conceptualize the skills formation process for the high priority multidisciplinary domain of business informatics. A holistic approach for efficient synchronization between the Life Long Learning paradigm and learning organization concept involves in progressive educational stages as a set of common activities performed with the aim to assist national education system in meeting the going demand for knowledge workers of today's global economy. The big challenge with public education system is that the young graduates need a fairly long period (12 - 24 month) to take up and become fully productive in real-life working environment. The other major issue is that resources are scared anyway and the increasing demands of skilled workforce may be compensated by the deep cooperation between the public education system and a corporate (or a consortium) program. A clustering program, developed by University POLITEHNICA Bucharest and, respectively Oracle Romania is chosen as a case stud. Also, the "BIN-Net" Socrates Erasmus program for master joint degree in common Europe will be presented briefly (http://www.dke.univie.ac.at/binnet).

Keywords. Life long learning, Learning Organization, Virtual University.

Motto: “Make the things simple, but not too simple” (Albert Einstein)

Introduction

Global competitive challenge and increased expectations of customers for product & support services within 5 - dimensions metrics (cost / quality / promptitude / product lifecycle management / one-of-a-kind customization) are compelling organizations to collaborate across time and geographic boundaries within new concept of Collaborative Networks [Camarinha, 2005]

Switching to Knowledge Society (KS) bring changes to all fields of socio-economical life: administration (e-government), business (from e-business towards k-business); education (e-learning) culture (media centers and virtual libraries), way of work (e-work, e-

research); a.s.o. The main driver for those changes is the "Internet-industry" and the "Web - Universe", which influences the way we live, work, do business, studying, communicate and even spend free time [Ghilic, 2005]. Business Ecosystems have an important role in transforming the society. Setting up virtual companies in most-field and their efficient management may have positive influence over both the entire social life and the understanding and acceptance of the future social role [Dumitrache, Stanescu 2005].

The traditional economy operates on the basis of limited resources that deplete when are used. In contrast, the information and knowledge continue to grow, even more so when we are using them "The characteristics of the networking knowledge economy, so different from those of the physical economy, demand new thinking and approaches by policy-makers, senior executives and knowledge workers alike" [Skyrme, 2000]

Knowledge networking is not case to define or describe. It is a rich and dynamic phenomenon in which knowledge is shared, developed and evolved. It is an anthropocentric process of human and computer networking where people share information knowledge and experiences to develop new knowledge for handling new situations. It is powerful juxtaposition of two important concepts-that of the strategic resource of knowledge, and that of human act of networking. Savage defines it as "the process of combining and recombining one another's knowledge experiences, talents, skills, capabilities and aspirations in ever-changing profitable patterns"[Savage, C.M.(1996)] In this context "Learning Organization" (LO) represent a promising concept to develop the new holistic approaches.

The last 12th ISPE Conference has already bring to our attention a challenging framework involving the knowledge modeling approach for enterprise architecture [Jorgensen, 2005]; [Lillenhagen, 2005].

One could define the Learning Organizations as entities that continuously expand their capacity to create their future. In the knowledge economy one approach is to create an environment and a culture that encourages knowledge generation and sharing, supports learning by doing and ensures that learning is incorporated into future activities, decisions and initiatives of an organization or community. In this respect (Hodgins [2], 2000) proposes the “learnitivity” model of a continuous spiral for conversion of tacit knowledge (such as know-how and experience) into explicit knowledge that can be captured and turned into new tacit knowledge gained from learning by doing.

In this context and in the knowledge based economy learning can be seen as an integral part of knowledge creation spiral that involves: performing, capturing, managing and learning. The Internet and the Web are the tools that make possible the process above and it is essential in the work of learning. Moving into the future, we look at virtual reality, mobility and eventually K-business – a business that markets and sells knowledge over Internet.

The present is structured according to the following schema: section 2 is devoted to define the generic model for continuous learning based on Hodgins learnitivity spiral model, section 3 describes the skills formation processes; section 4 summaries the experience for developing a joint degree European master in business informatics (BIN-NET project in progress). Finally some conclusions and further work are presented.

1. Continuous learning spiral model

The model described in Figure 1 inspired by Hodgins learnativity spiral actually depicts a real situation in which the authors needed to map existing learning programs available with various corporations in order to assist the public education to fulfill the scope of providing better prepared graduates able to meet the IT market expectations.

The authors developed their concept out of the experience with several Oracle educational programs (i.e. Oracle Academy, Oracle Academic Initiative, Think.com, a/o). For example the Oracle Academy curriculum consisting mainly in Data Modeling and PL/SQL programming was proposed and accepted by the Romanian Ministry of Education for the secondary school level deployment [7]. The program targets 1500 secondary schools with Math/Informatics profile. It is supposed and expected that K12 graduates that follow university formation may be able to continue the RDBMS study with programs adapted to higher education expectations. In this respect the "Oracle Academic Initiative" is available within 15 universities across Romania. As the public education system evolves towards the Bologna model (3 + 2 + 3) two other programs were necessary to fulfill the last two stages, master and PHD respectively. Indeed several master programs are being developed together with a number of universities or departments having as particular flavor the possibility of the students to attend an internship stage at Oracle facilities premises. Also, the PHD program to be launched aims to engage research topics proposed by Oracle and developed by PHD students during their PHD studies at certain universities. With this cycle the authors estimate that graduating students are up to speed for the challenges of real world organizations.

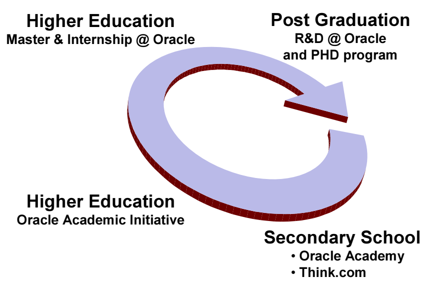

Figure 1 - Development Spiral Towards Knowledge Economy

(Geoffrey A. Moore, 1999 a; 1999 b) proposed a model of new technology adoption cycle that follows the profile of a normal distribution curve described by the following function:

$$y = 1/sqrt(2) * e **(x^2/2)$$

The learning process induced by a certain technology follows the same pattern. On a broader perspective a disruptive technology replaces an old one and the cycle is repeated. An example is data communications: telegraph, telex, facsimile, and internet. Another example is computer systems: mainframe -> minicomputer -> personal computer -> laptop -> hand held [6]. The diagram in Figure 2 provides a graphical interpretation of this model: if an organization or community is not able to adapt fast enough to market or social driven renewal processes, for instance the adoption of a new technology, it might face increases risks of failure or regression on medium and long term. Regarding the adoption of new technologies the authors would highlight the fact that all economies in transition in SEE have been market driven towards development by the adoption of new technologies (Internet, mobile communications, environmental protection, a/o) leading towards spectacular results for the past 15 years.

The problem is how to ensure the positive slope of the continuous learning process today. A strategy for skills formation was conceived (Figure 3). The authors of the paper consider that the skills formation process is following a spiral trend, covering different stages of the educational process.

2. Concept of skills formation

Corporate and governmental organizations are significantly shifting their strategies from hierarchic work structures and departmental layers towards team –based flat organization. This human centered holons may cut across responsibilities.

2.1 Emerging process

The present concept emerged as a result of the authors multiple experiences in implementing educational programs at different levels. The model considers that each individual, or groups of individuals enrolled in educational programs, follow a skills evolution curve, consistent with Gauss curve, which is specific to each formation module. In spatial perspective, the skills evolution curves covering the entire skills formation cycle (for an individual or group of individuals) are displayed on a spiral crossing different plans of the educational process. The transition from an educational plan to the superior one is performed through inflexion point generically called "High Knowledge Degree Inflexion Point (HKDIF)" (see picture bellow). The proposed model considers that during the educational process is very important to determine the inflexion point for various educational programs or target groups in order to maximize the effects of the educational process at the level of each individual as well as at the organizational level.

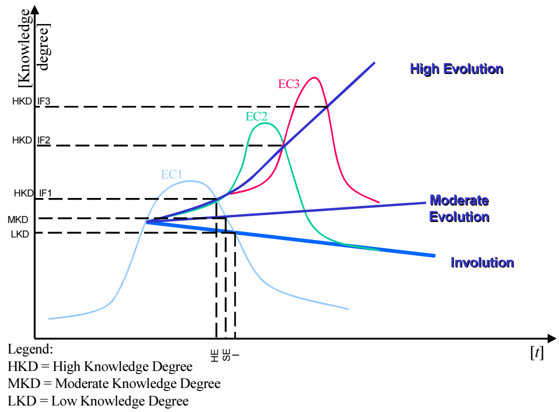

Figure 2 -Skills Formation Evolution Process

2.2 Evolution process

The following conceptualization for the skills formation evolution process can be defined as follows:

– When passing though a skills formation stage the individuals evolve till reaching the inflexion point of the evolution curve, defined as a normal distribution function (Gauss bell). In this point - HKD in Figure 2, located on the descending slope of the bell profile there are three types of behavior occurring on long term:
  - High evolution, transposing the individual at the beginning of a new evolution curve placed on the ascending trend of the development spiral;
  - Moderate evolution or stagnation, maintaining the individual on the same evolution curve, but at the superior part of it;
  - Low evolution, establishing a descending trend for the individual professional development.

The HKD inflexion point of each evolution curve specific to the development stages are extremely important for the educational process because it represents the optimum for transition to a superior stage. At the same time, the identification of this point at early stages allows optimization of the educational programs according to the behavior of the trainees and provides good bases for the management of the moderate evolution stages. This model could be used in providing estimations concerning the adoption of the new technologies and penetration rates of these technologies according to the addressed target groups.

Following the analysis of the skills formation processes observed along several stages covered by the chain in Figure 1 the authors propose the pyramidal concept presented in Figure 3. The main hypothesis of the concept assumes the skills formation process follows on long term the pattern of a “spina minabilis” logarithmic spiral.

This spiral represents the set of the HKD inflection points of the families of evolution curves earlier described, following the evolution of an organization or community over multilevel stages of development / training stages.

Starting from the spatial distribution hypothesis of the skills formation evolution processes, the authors concluded that in the formation of a professional individual there are 3 stages as depicted in Figure 3: Basic formation, Specialization and professional.

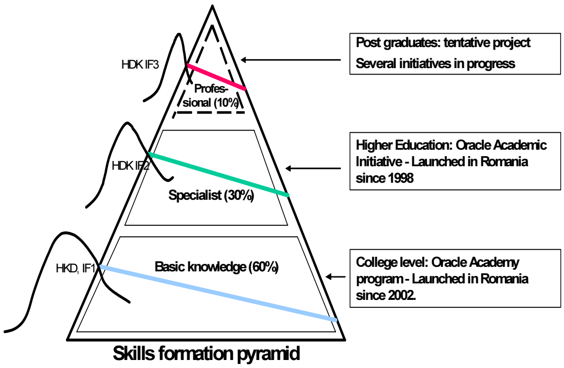

Figure 3 - Spatial Positioning of the Skills Evolution Curves

Considering a group individuals/community that are subject to a formation program, we have presumed that 60% would follow the basic knowledge stage, 30% would be interested in advanced (specials) training and only 10% in a professional track. This hypothesis is based on the observation of the number of students enrolled in the initial phases of the continuous learning program out of which just a reduced number will follow PHD and post-PHD programs.

3. Developing a joint degree European master in business informatics

Over the last decades, Universities have offered various courses in Management, Information Technology, Computer Science, Software Engineering and more recently Information Systems, Information Management and Business Informatics. Various courses have been established at many universities and in particular the growth of information technology and information systems related programs is expected to continue. However, recently there are concerns that the number of students registered for information system related courses could stagnate or fall.

First emerging in 1970s as a technology oriented course in business, over the last three decades Business Informatics is increasingly accepted as a field of research and study in Information Systems. Like Information Systems, Business Informatics focuses on business information systems as socio-technical systems comprising both machines and humans. A growing number of universities in the German-speaking countries offer study programs in Business Informatics with increasing numbers of graduates.

In contrast to informatics, which primarily concerns the technology of information and communication systems, business, which focuses on management functions, Business Informatics centers around business information systems with the objective of supporting business functions. Business Informatics concerns the concept, development, implementation, maintenance and utilization of business information systems. In addition to managing the information systems, Business Informatics also focuses on the relationship between humans, business functions, information and communication systems and technology. As a science discipline business informatics is generally categorized as:

- Applied science that studies real world phenomena,
- Formal science that creates and applies formal description methods and models
- Engineering discipline that systematically design and constructs information and communication systems.

Therefore Business Informatics is interdisciplinary and can be summarized as a socio-technological and business oriented subject with *engineering* penetration. In the German-speaking areas Business Informatics courses in general (still) lead to a *Diploma* after five years of study. Thus, the equivalent qualification in the UK is a Master degree. In the UK, information systems courses are offered at MSc level in a significant number of universities. These fall into two kinds – “conversation” courses and “add-on” courses. The conversation courses are offered to graduates in disciplines other than computing, and aim to provide a competence in computing disciplines and the business applications of information technology. In general they do not provide a deep study of either discipline, nor of information system engineering aspects. The add-on courses are typically offered to graduates in Computer Science, and offer an understanding of information management and the place of IT in business processes. Some of them offer advanced courses on business studies, information management and information strategy.

Internet education is a kind of distance teaching / learning that gains terrain every day. Support courses are stored in specific digital forms and accessed through a common web browser (rarely a dedicated browser) by students, in their own pace. Learning materials are presented as multimedia (text, sound, images, animations, movies) and hyperlinks (a structural model where access to other information is made through multiple links from a single page). Other pages allow returning in-depth study by jumping to pages with similar subjects or other kinds of information. Comparing to traditional education, we can see some of the advantages of distance education through internet, making it usable, at least for now, in universities and permanent education, on the model of open communities in super developed countries. First of all, all course resources may be accessed simultaneously by many students. Curricula scope will be wider than the present one, offering multiple ways of acquiring highest level knowledge in all fields. Audience is obviously higher; distance education may involve students that can not participate in traditional system. Access to

local, regional and national networks ties students from different social, cultural, economic environments and with different experiences. Courses may be studies step by step and repeatedly. Computers use varied and extremely flexible software packages, giving the student a maximum control over content information. Synchronous and asynchronous interaction between professor and students may be complementary. There is the possibility of creating a pedagogic group (team teaching) for transmitting knowledge from a certain domain and involving educators that are otherwise unavailable for various reasons.

Technologies are interactive, allowing for a complete feedback in a real time and quantitative and qualitative evaluation in an easy way, by the most appropriate evaluators. Starting with our research for clustering project to promote concurrent enterprising paradigm (Stanescu 2000) the emerging framework to develop learning organization, (shown in figure 4.) may be defined as an intersection entity between extended university and extended enterprise.

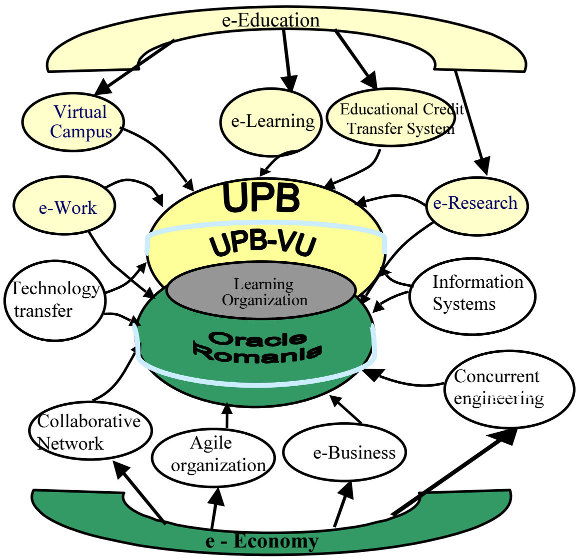

Figure 4 – Emerging framework to develop a specific learning organisation

Conclusions and future work

One could define the learning organizations as entities that continuously expand their capacity to create their future. In the KE one approach is to create an environment and a culture that encourages knowledge generation and sharing, supports learning by doing and ensures that learning is incorporated into future activities, decisions and initiatives of the company. Further efforts are focused towards ontology based E-Learning. This idea became obvious after understanding how the E-Learning cube was useful to the GSM

operator. Ontology was defined as a formal, explicit specification of shared conceptualization. For the purpose of this paper "conceptualization" refers to the abstract model of the E-Learning Cube.

The term "Explicit" means that the type of concepts used and the constraints on their use are explicitly defined. "Formal" refers to the fact that the ontology should be machine understandable. There has been considerable effort put into the Meta languages to model VE processes and structures. The term "Shared" reflects the trend of ontology as being able to capture consensual knowledge. Efforts are going both in the scientific direction as well as towards real world implementations of E-Learning solutions for Collaborative Networks.

The authors are implementing this concept within the Oracle Educational programs carried out in Romania which are covering a very wide range of ages from 7 years old (think.com) to 25 (PHD programs). The authors will continue their research towards the skills formation conceptualization because of the applicability in the knowledge based economy.

Acknowledgements

This paper represents the beginning of a research undertaken, not a final result, in concerning with the new strategy for educational process witch is necessary to be developed within learning organization. The author do express there gratitude for ideas exchanging among the BIN-Net partners (prof. dr. Dimitris Karagiannis, as project coordinator, Mrs. Maria Schmidt-Dengler, Mrs. Elena-Teodora Miron, University Of Vienna; prof. dr. M. Owoc; dr. Ewa Losiewicz, Wroclaw University of Economics; dr. Istvan Bessenyei, University of West Hungary; doc. rndr. Michal Gregus, "Comenius" University of Bratislava; doc. ing. Petr Doucek Academy of Economy Science, prof. dr. Joaquim Filipe Escola Superior Tecnologia Setubal; prof. dr. Marcin Sikorski; Gdansk University of Technology; prof. dr. eng. Anca Purcarea, University Politehnica of Bucharest; prof. dr. eng. Emil Popa, assistant Cristina Elena Aron University "Lucian Blaga" Sibiu).

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Applications in CE

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The Evaluation of Advantageous Industries and the Analysis of Their Global Logistics Operations – Case Study of Precision Machine Tool Industry

Amy J.C. Trappey[a], Charles V. Trappey[b], Gilbert Y.P. Lin[a], C.S. Liu[c] and W.T. Lee[c]
[a]*Department of Industrial Engineering and Engineering Management, National Tsing Hwa University, Hsinchu, Taiwan; trappey@ie.nthu.edu.tw, Tel: +886-3-5742651, Fax: +886-3-5722204*
[b] *National Chiao Tung University, Hsinchu, Taiwan; trappey@cc.nthu.edu.tw*
[c]*RFID Technology Center, Industrial Technology Research Institute, Taiwan; WT_Lee@itri.org.tw*

Abstract. This research studies the development and operations of advantageous industries' logistics hubs in Taiwan. Based on a comprehensive analysis of related data, we quantitatively and objectively identify Taiwan industries on a scale from low to high advantages. The advantage ranking, combined with economic production data and other global indicators, enables us to place the industries into categories. Based on the categories of advantageous industries, selective companies are targeted and surveyed to depict their current and improved operations of global logistics and distribution hubs. The systems underlying these logistics/distribution hubs are modelled using INCOME, an integrated system analysis tool designed to capture, describe, and analyze business processes with various views. Given the set of business process models, we provide an approach for industries to rapidly implement best logistics practice for global trades. The models enable companies to rapidly configure and test multiple hub models for disaggregated global production and distribution chains. We use the precision machine tool industry as the case example to demonstrate the proposed methodology.

Keywords. Advantageous industries, Logistics, Precision machine tool industry, Global trades

1. Introduction

Industries in Taiwan have continuously improved their global competitiveness through reducing overall costs and increasing profit margin. One of the key approaches for cost reduction is to improve the efficiency and efficacy of global supply chain and logistics management. Electronic commerce and associated business-to-business transaction capabilities have changed the way that the modern supply chain operates. The integrated information system enhances the global inventory visibility, reduces logistics costs and improves customer service by decreasing shipping and receiving cycle times, increases shipment and inventory accuracy, and decreasing lead-time variability [15].

Related research [13] [19] shows that product stock can be consolidated and third-

party logistic (3PL) services can be utilized to enhance product and material's availability just-in-time (JIT). Related research shows that Taiwan's logistics costs are currently about 13% of the GDP (Gross Domestic Product) [16]. Based on 13% of Taiwan's GDP (i.e., US$ 300 billion), the total Taiwan's industries logistics spending amounts to approximately US$ 39 billion per year. The percentage (13%) is relatively higher than other developed countries, such as 10% in UK (United Kingdom), 10.5% in USA, and 11.4% in Japan. Thus, the further reduction of logistics cost in Taiwan will help improve overall competitiveness of our industries. World-wide manufacturing networks require new models that integrate the material and information flows covering the whole life cycle. Logistics processes are the integrating element of globalized production, especially for virtual factories. The importance of IT in industry has caused a paradigm shift in logistics [12]. This research indicates that the development of logistics hubs, utilizing information and communication technology, will increase information sharing, build robust connections between channel members, and decrease production uncertainty.

Multiple factors and their effects are processed and measured during decision making [4]. This research intends to classify Taiwan industries into the ranks of advantageous industries. In order to quantify the weight of classified factor, this research combines fuzzy set theory with the analytic hierarchy process (AHP) to select and evaluate which of Taiwan's industries should be classified as advantageous. The AHP, developed at the Wharton School of Business by Thomas Saaty [17] in1971, allows decision makers to model a complex problem in a hierarchical structure showing the relationships of the goal, objectives (or criteria), sub-objectives, and alternatives. More and more researchers realize that AHP is an important generic method applicable to various fields, such as conflict resolution, project selection, budget allocation, transportation, health care and manufacturing processes [1] [5] [11]. Although the AHP already has applications in various fields and has produced significant results, some scholars have found certain deficiencies of AHP [2] [7] [18]. With the AHP not being able to overcome the deficiency of the fuzziness during decision-making, Laarhoven and Pedrycz (1983) [14] have evolved Saaty's AHP into the FAHP, bringing the triangular fuzzy number of the fuzzy set theory directly into the pair wise comparison matrix of the AHP. The purpose is to solve vague problems, which occur during the analysis of criteria and the judgment process. There are many fuzzy-AHP methods that are proposed by various authors. Tolga et al. [3] explain that these methods are systematic approaches for the alternative selection and justification using the concepts of fuzzy set theory and hierarchical structure analysis.

After identifying a set of advantageous industries, we investigate current logistics hub applications in these industries as their as-is process models. We seek to reduce logistics cost, increase logistics efficiency and, hence, develop the improved, to-be, process model for logistics operations. A case is provided to demonstrate the approach at work to promote the best practices of advantageous industries. This paper is organized into four sections. Section 2 describes the evaluation approach and Fuzzy AHP methodology for identifying the advantageous industries in Taiwan. Section 3 describes the case in precision machine tool industry and defines the current (as-is) and improved (to-be) logistics operational models. Finally, the conclusions are drawn in Section 4.

2. The Advantageous Industry Investigation Approach

This investigation approach for the ranking of advantageous industries can be divided into three steps. They are (1) categorization of Taiwan industry, (2) advantageous industry selection and ranking, and (3) logistics model research.

2.1 Categorization of Taiwan Industry

In this research, we use the ITIS (Industrial Technology Intelligence Services) [10] industry categories, which are categorized based on the Taiwan government industry classification scheme, as the base to select the advantageous industries. Our research sponsor, ITRI (Industrial Technology Research Institute), requested that the manufacturing industry be the major focus and there are 198 industry classes under manufacturing. Industries, which can not produce real/physical products, would not be listed and evaluated in this research.

2.2 Advantageous Industry Selection and Ranking

2.2.1 Self-Definition of Advantageous Industry

Industrial competitiveness is a reflection of a company's operational efficiency, market-demand flexibility, R&D capability, its market share, and ability to improve status quo. An enterprise must have competitive advantage to survive and succeed. The concept of "competitive advantage" is proposed by Ansoff [8] in 1965. The competitive advantage of a company is its ability to offer greater value to its customers, either by means of lower prices or by providing greater services. Sometimes, competitive advantage can be a distinctive competence of holding superior resources or technology [6]. According to how we define advantageous industries, Figure 1 provides the working definition of advantageous industries. It reveals the internal and external factors structure and the decision processes based on these factors. Internal factors include current contribution and business growth rate. The current contribution basis is adjusted for the state of the general economy. The business growth rate measures changes in production between two different periods of time. It shows both short-term and long-term growth and decline. External factors include barriers of entry that prevent or hinder companies from entering a specific market. Both internal and external factors impact the competitive advantages of firms and firms with the greatest advantages achieve the highest goals.

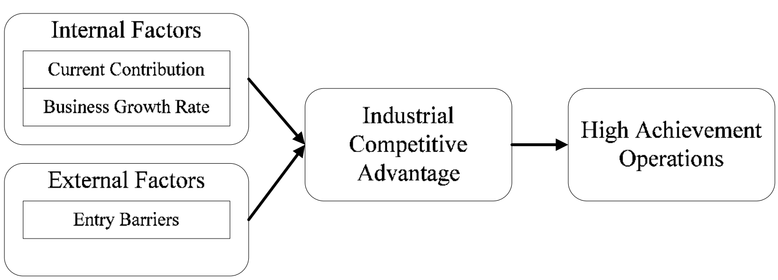

Figure 1. An evaluation of advantageous industries

2.2.2 Methodologies of Advantageous Industry Selection

In this research, six industrial indicators are combined to analyze and compare the potential advantageous industries. These indicators are listed in Table 1. We only choose the internal factors for evaluation based on the related national economic statistics and industrial reports. Concerning external factors, we will think about related qualitative factors to reveal after field research survey in the future work

Table 1. Industrial indicators

Views	Indicators
Current Contribution	**Production Value:** The annual total monetary value of production.
	Export Value: The annual total monetary value of export.
	Export Percentage: The ratio of export value and the gross output value.
Business Growth Rate	**GDP Growth:** Measures total output within the country and is computed as the sum of the gross value or income from each sector of the economy.
	Export Trade Growth Rate: The annual growth rate of export.
	Industrial Production Index: Measures changes in production between two periods of time.

The FAHP approach in this study extends the AHP by combining it with the fuzzy set theory to achieve advantageous industries selection of ranking Taiwan industries on a scale from lower advantage to higher advantage. The procedure is described as follows.

Step 1. Hierarchical Structure Construction

The first step in applying the fuzzy AHP is to construct a hierarchy of alternatives and the criteria for choice, as shown in Figure 2. The main goal of the desired problem in this study is the selection of advantageous industries. Hence, the advantageous industries are placed on the top layer of the hierarchical structure. Under the goal and on the second layer lie the evaluation criteria for current contribution and business growth rate in the hierarchical structure. Next the sub-evaluation criteria (i.e., production value, export value, export percentage, GDP growth, export trade growth rate, industrial production index) are placed on the third layer of the hierarchy. Finally, on the bottom layer of the hierarchical structure are the 198 manufacturing industry alternatives to obtain the final goal.

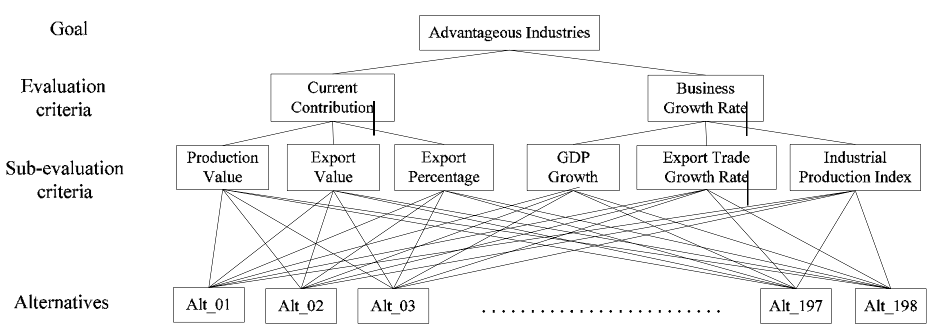

Figure 2. Hierarchy of the advantageous industries selection

Step 2. Linguistic Variables Evaluation and Fuzzy Numbers Translation

A questionnaire was designed for subjective assessment and model experts' opinions. Based on the surveyed standards from these experts, the data is used to evaluate the Current Contribution $E_j, j = 1,2,\ldots,J$ of J industries and Future Contribution $A_k, k = 1,2,\ldots,K$ of K industries. We were surveyed 11 logistics domain experts, $M_i, i = 1,2,\ldots,I = 11$, including industrial experts and academic professors. The linguistic variables are weighted according to experts' opinions. Table 2 lists the fuzzy numbers that define the fuzzy membership functions. Afterwards, the normalized fuzzy numbers representing experts' opinions are derived by translating the linguistic variables into triangular fuzzy membership functions [7] as shown in Figure 3.

Table 2. Mapping table of linguistic variables and fuzzy numbers

Linguistic Variables	Fuzzy Numbers
Very uncritical	(0,0,0.3)
Uncritical	(0,0.25,0.5)
Common	(0.3,0.5,0.7)
Critical	(0.5,0.75,1)
Very Critical	(0.7,1,1)

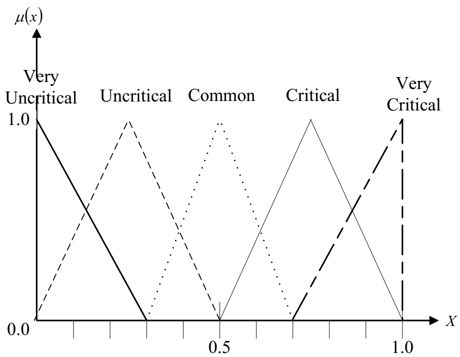

Figure 3. Fuzzy membership functions support the FAHP

Step 3. Calculate the Weights

The Eqs. (1) and (2) are used to calculate the fuzzy estimated value of the future and current contributions respectively. Those two estimated value integrate each estimated weight according to *I* experts and each definition of the two scopes.

$$\overline{EP} = \frac{1}{I \times J} \sum_{i=1}^{I} \sum_{j=1}^{J} \left(\sqrt{EX_j \times \overline{EW_{ij}}} \right) \cong \left(EP_1, EP_2, EP_3 \right) \tag{1}$$

$$\overline{AP} = \frac{1}{I \times K} \sum_{i=1}^{I} \sum_{k=1}^{K} \left(\sqrt{AX_k \times \overline{AW_{ik}}} \right) \cong \left(AP_1, AP_2, AP_3 \right) \tag{2}$$

$\overline{EP}$ will integrate all the fuzzy estimated value. Under the standard of Current Contribution, $E_j, j = 1,2,\ldots,J$. EX_j will be the industrial estimated value and $\overline{EW_{ij}}$ will be the fuzzy weight decided by expert i.

$\overline{AP}$ will integrate all the fuzzy estimated value. Under the standard of Future

Contribution, $A_k, k = 1,2,\dots,K$. AX_k will be the industrial estimated value and $\overline{AW_{ik}}$ will be the fuzzy weight decided by expert i.

Step 4. Defuzzification

In this study, the Center of Gravity method is adopted to defuzzify the fuzzy estimated value.

$$\overline{E} = \frac{EP_1 + 2\times EP_2 + EP_3}{4}, \quad \overline{A} = \frac{AP_1 + 2\times AP_2 + AP_3}{4} \qquad (3), (4)$$

$\overline{E}$ is the synthetic estimated value of industrial Current Contribution and $\overline{A}$ is the synthetic estimated value of industrial Future Contribution.

Step 5. Applying AHP

Apply AHP to establish the judgment matrix and estimate relevant weight W_E, W_A of Future Contribution and Current Contribution and complete consistency test.

$$W_E = \frac{\sum_{i=1}^{I} W_{Ei}}{I}, W_A = \frac{\sum_{i=1}^{I} W_{Ai}}{I} \qquad (5), (6)$$

W_E stands for the weight of Current Contribution while W_{Ei} is the weight of industrial Current Contribution given by expert *i*; W_A stands for the weight of Future Contribution while W_{Ai} is the weight of industrial Future Contribution given by expert *i*.

Step 6. Receive Merger Assessing Value and Ranking Candidate Alternatives

By multiplying the weight and the estimated value, the final merger assessment value TA is calculated. The advantageous industries are selected from the ranking the candidate alternatives according to *TA* value.

$$TA = W_E \times \overline{E} + W_A \times \overline{A} \qquad (7)$$

2.3 Logistics Model Research

This research conducts field surveys of the classified leading companies of the advantageous industries in Taiwan to realize and clarify their current (as-is) logistics models. Using Petri Net theory, the business process models and the related logistic operations are studied and modified to construct idealized logistics processes (to-be). The to-be models are then used to create generalized logistics hub solutions. The solutions are used to provide consulting, advice, facilitate logistics implementation, and facilitate change in existing logistics services.

3. Case Study of Precision Machine Tool Industry

3.1 Industry Background

The precision machine tool industry in Taiwan is an export-oriented industry. Over 80% of the final products in this industry are sold abroad. The export production value is ranked as the top 4 in the world. Furthermore, the precision machine tool industry in

Taiwan is a high customized industry, where more than 80% products are CTO (configuration-to-order), and 20% are MTO (make-to-stock). A-Company is one of the major manufacturers in the precision machine tool industry in Taiwan and has taken pride in its service and the outstanding quality of its products for more than 30 years. The company offers a broad range of products such as CNC processing machinery, woodworking machinery, saw blades, lumber, panel (Macro Fiber Composite, MFC) and construction materials with many cross-industry applications. A-Company continues to expand its experience and expertise to offer fast and efficient sales and service operations in markets throughout the world. Therefore, this section uses the A-Company as a case study to provide a detailed description of its logistics strategy for other Taiwan companies that maybe adopt global logistics management.

There are three types of business model in the A-Company. First is direct sale model which is direct sale by the manufacturer or its subsidiaries and goods are directly shipped to customers. Direct sale occupies about 40% of the sales. Second is the agent model which is just like a match maker. The overseas agents buy goods, save in their inventory, and then sell to end customers but not concerns with the after-sale service. It occupied 20% of the sales. The last type is an integration model of agent model and direct sale model which combines the after-sale service. This model transports products and saves in the subsidiaries inventory, after abroad agents made contract with customers, products will deliver to the end customers from manufacturer. This model occupies another 40% sales.

3.2 As-Is Logistics Model of After-Sales Service

Since the products in this industry are high price, high value goods that require tracking of use-by dates and after-sales service. These two factors are a major business emphasis. In the case study of A-Company, we describe the process of after-sales service.

The as-is logistics model of the after-sales services for maintenance and repair are shown in Figure 4. The maintenance and repair operations run through the same process. When the agents receive demands for repair or maintenance requests, the first action is to check the degree of after-sale service. Agents and A-Company both have repair and maintenance ability. The difference is that the agents only have preliminary maintenance and repair ability. According the situation, agents will judge whether to provide repair or maintenance services. If agents can not provide the service, they will transfer the request to A-Company. If they have the ability to repair, agents will provide the service and go on to perform the inner process. The inner process involves calculating the quantity of repair components, and checking the components inventory. If agents have enough quantity, they will assign engineers to repair machines. After repairing/maintaining machines, engineers will create and save the repair/maintenance record into the repair/maintenance data. If agents have insufficient stock, they order components from A-Company. If A-Company has stock, A-Company will hire a logistics service provider (LSP) to pick and transfer the goods for maintenance and repair. If A-Company is out of stock, then a backorder message is sent to the agent. There are some disadvantages of the as-is model. First, the repair and maintenance are repeated processes steps. The agents and the A-Company will hire overlapping engineers to stand by to resolve the immediate demands. Second, the processes do not integrate logistics information. Shippers (A-Company or agents) can not control the arrival time of components for customers. Arrival times are planned independently without any exchange of information, which makes planning an extremely difficult task.

Finally, there is no e-supply chain management and the on-line availability of information. If we could reengineer the process of the after-sales service, we can save more resource and achieve efficiency services for customers in real time.

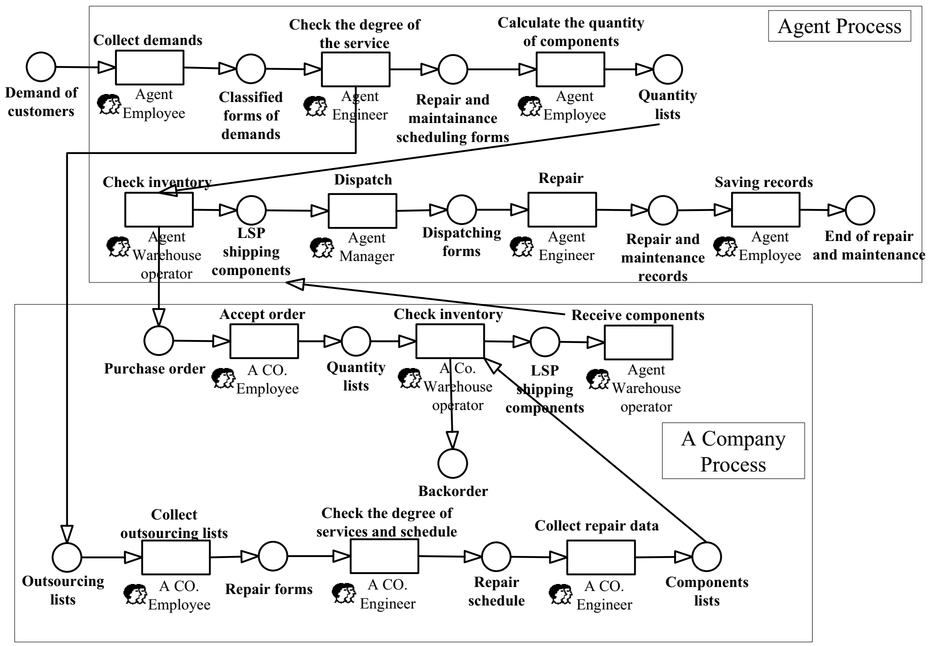

Figure 4. As-is after-sales service logistics model

3.3 To-Be Logistics Model of After-Sales Service

In the to-be after-sales service model, this research separates the after-sales service into maintenance and repair parts. We also provide a central logistics hub information system to support transmit management and monitor inventory information. The main idea of the to-be after-sales maintenance service logistics model is that maintenance can be schedule, so it doesn't have to run through the same process with repair. Since customer companies can decide a product's maintenance cycle, they can input maintenance time into logistics hub information system. The logistics hub will collect and schedule the maintenance time. When the time for maintenance is near, the system will remind the warehouse engineers to check the inventory of the components. When the components are ready, then the maintenance department will inform the customer that it is time to maintain their machine tool. They will schedule the time and go to the customer location to maintain the machine tool.

Considering the to-be repair model, the demand for repair is not predictable. The agents and the A-Company will have to have some inventory of components. The manager can use the interface via logistics hub information system to check the inventory in the warehouse immediately. On the other hand, the shippers and customers can use an Internet browser to track the goods during shipment via logistics hub

information system. The detailed process of the to-be after-sales service logistics models for maintenance and repair are shown as Figure 5 and Figure 6.

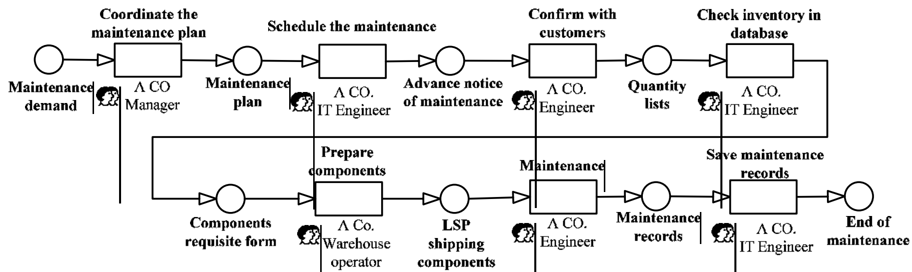

Figure 5. To-be after-sales service logistics model (Maintenance)

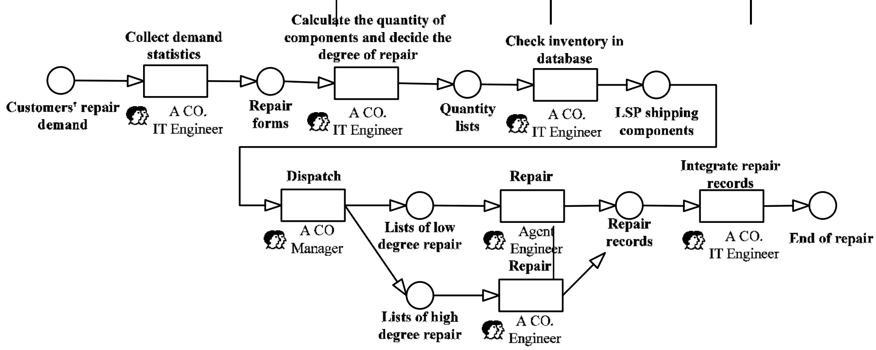

Figure 6. To-be after-sales service logistics model (Repair)

4. Conclusion

This paper provides a method to investigate and analyze advantageous industry logistics. FAHP is used for the selection of advantageous industries. Afterwards, field research is used to investigate the current logistics hub applications of these advantageous industries and the as-is business process models are drawn using software called INCOME by Get Process ® [9]. After the as-is models of the leading industry sectors (e.g., case industry) are derived, we build to-be business process models to generalize the hub applications with the goal to improve the business processes, to reduce logistics costs, to increase logistics efficiency, to enhance information concurrency and, hence, promote industry competitiveness across other industries in Taiwan.

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Developing Web Application to Support Effective Recycling and Material Circulation

Sang-Jae SONG [1]
Department of Mechanical & Intelligent Systems Engineering, Hiroshima Institute of Technology, Japan

Abstract. This paper proposes a new perspective on improving product service and maintenance through effective utilization of feedback information on recycling in the whole product life cycle stage. To develop an analytical model and tools, simulation optimization techniques are considered, and diagnosis based on alarm conditions and acknowledging warnings indicates is also developed to continuously improve in less energy consumption and environmental impacts.

Keywords. Recycling, Web Application, Life-Cycle Modeling, Simulation, Diagnosis

Introduction

Current production methods and consumption patterns are not suitable on a deteriorating natural resource, as well as many types of pollutions and disposal [1]. This paper proposes a better way to achieve less energy consumption and effective material circulation. The better way which aims to comply with environmental, technical, and economical requirements is to establish a Java-based Web application for facilitating continuous improvement of products with the view of optimizing all elements involved in the life-cycle of the product. In particular, the innovative approach capable of leading to major saving in materials, energy and life-cycle costs stimulates information exchanges between manufacturers and their suppliers toward synchronizing life cycle decisions on recycling and maintenance activities, as well as production management. The overall structure of Web-based application is shown in Figure 1.

1. Web-Based Application: Incorporating Life-Cycle Decisions

An appropriate method to analyze and assess the environmental impact of an industrial product throughout its life-cycle from the acquisition of raw material in nature to the disposal of the used product to earth is significant for successful implementation of effective material circulation. In order to successfully achieve resource and energy saving, less emission as well as overall cost effectiveness, life-cycle analysis has been recently recognized as a viable approach in which innovative product design of a product and all its related processes in the manufacturing system are taken into consideration simultaneously. At the same time, a product should be maintained with a minimum impact on environment and with a minimum expenditure of resources.

[1] Department of Mechanical & Intelligent Systems Engineering, Hiroshima Institute of Technology, 2-1-1, Miyake, Saeki-ku, Hiroshima 731-5199, Japan, E-mail: song@cc.it-hiroshima.ac.jp

An exchange of various types of environmental information and product data that meet the requirements of technical and ecological assessment must be performed across enterprises in the whole product life-cycle stages. The Web-based application incorporating forward and reverse supply chain decisions seeks to facilitate an effective integration of manufacturing decision processes throughout all life-cycle phases of the product, such as material production, product and process design, manufacture, use, and its ultimate recycling (see Figure 2). The recycling-conscious decision-making for Web-based system consists of the following four views [2]:

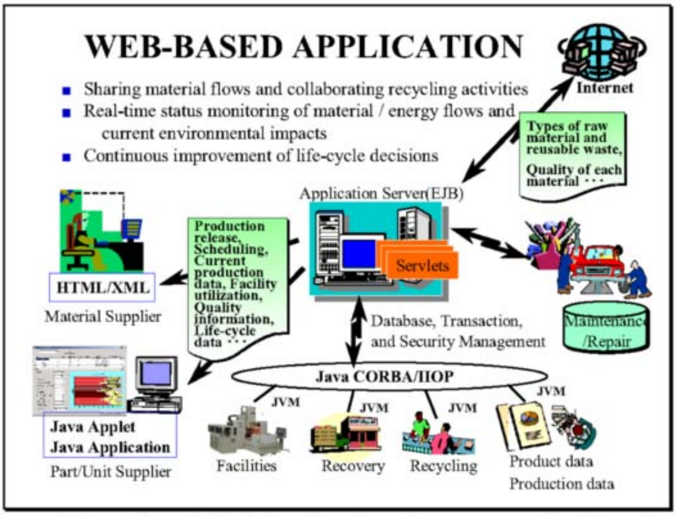

Figure 1 Java-Based Web Application: Structure and its Functions

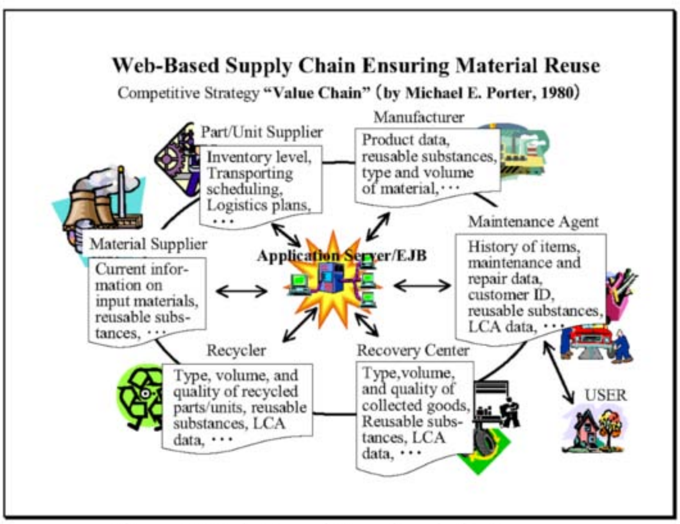

Figure 2 Web-Based Supply Chain Systems

1. Manufacturing technology view: considering the recycling and resource-saving in the early stage of product and manufacturing process from the viewpoint of whole life-cycle analysis.

2. Production management view: integrating environmental issues into the manufacturing decision processes to determine optimal production quantities for recycled parts and machining parts towards a more sustainable pattern of production, as well as for rapid product development to low cost, relatively quickly and with minimum resources.
3. Optimal incentive mechanism view: enhancing re-production and re-use of end-of-life products as well as stimulating recycling activities. It is significant since the logistics for supporting recovery are under the indirect control of the company.
4. Analyzing the effectiveness of recycling activities: the cost-effectiveness analysis is introduced for successful implementation to recycling-conscious manufacturing.

2. Essentials of Life-Cycle Modeling

2.1 Energy-Optimizing Life-Cycle Assessment

An energy based life cycle criterion will be used for the aggregation of the different environmental impacts to assess and estimate an overall environmental indicator. The multi-attribute environmental assessment for each unit material production can be evaluated continuously with five impact categories at each life cycle stage as follows:
(1) Energy consumption of oil, coal, natural gas, and electricity, unit [MJ];
(2) Resource usage of pure materials and ancillary substances, unit [Kg];
(3) Emission to air, unit [g CO_2-eg];
(4) Waste of hazardous, slag, ashes, and bulk, unit [Kg];
(5) Degree of recycling, unit [%].

Each impact criterion has two types of life-cycle assessed value: one is of raw material and the other is of recycled material. The environmental data will be updated periodically by periodic data collection. With desire input of material properties and manufacturing conditions as well as environmental requirements, the system is capable of selecting a subset of appropriate materials that meet certain user-specified requirements. In many cases environmentally best solution selected from such subset implies trade-off situations [3], where improvements to some of the product's characteristics may produce an additional impact in others. One alternative, for example, may have lower energy consumption, but then lead to a greater emission of toxic substances than other alternatives. The trade-off situation can be overcome with both energy-based life cycle assessment techniques and weighted normalization techniques for transforming and aggregating various unit types into a standard key unit [3]. The process of normalization comprises three procedures: individual assessment, normalization, and weighting procedure.

The weighted normalizing technique consists of two inherent assessment procedures: aggregated impact assessment and individual impact assessment. The latter aims to assist decision-maker for selecting environmentally safe material through the whole life-cycle. On the other hand, the individual impact assessment treats nonequivalence of environmental impacts between different substances in the result of the life-cycle assessment through the use of the two factors: equivalency factors and weighting factors.

In each impact category the impact potentials for a customer-engineered product are given as the sums of the estimated value of all individual substances. For selecting environmentally superior alternative, the aggregated impact criterion of energy at a life cycle stage $s(\in S)$ is then given as,

$$AE_s = \sum_{i \in I} w_{si} e_{si} Q_i + \eta(\sum_{j \in J} w_j e_j Q_j) + \xi(\sum_{k \in K} w_k e_k Q_k) \quad (1)$$

where w_{si} and e_{si} denote weighting factors and equivalency factors between a substance i and standard key substances s, and Q_i means a consumption of substance i. η and ξ represents equivalency factors for emission to air and resource usage including waste which are expressed as a corresponding quantity of energy.

2.2 Optimizing Life-Cycle Decisions

The essential objective of Web-based information systems is to enhance the recycling activities and better material circulation, as well as improving environmental impacts as much as possible continuously. To achieve this, a goal programming model is developed corresponding to the minimization of total energy consumption in four major life cycle stages such that material acquisition, production, maintenance, and recycling. The life-cycle decision model must be satisfied following all constraints in setting up lower limits L and upper limit U for given functional requirements.

(Material) Considering constraints for mechanical strength.

$$S^L \leq s_i(m,h,d) \leq S^U \quad (2)$$

where mechanical strength of a certain material, m will be influenced by the geometric shape, h and dimensions of the part, d.

(Manufacturing Method) Tolerances and surface roughness required of each surface will be dependent on manufacturing processes selected p.

Tolerances: $T^L \leq t_{ij}(P) \leq T^U$ (3)

Surface roughness: $W^L \leq w_{ij}(p)$ (4)

(Geometric Shape) The best combination among material, shape, and dimensions of each surface at the lowest possible life-cycle cost depends on the specified function expressing the mode of load *g(d)* and given functional requirements.

$$D^L \leq d_{ij}(h,m,p) \leq D^U \quad (5)$$

$$g_i^L(d_{ij}) \leq g_i(d_{ij}) \quad (6)$$

(Recycling) Recycling rate ζ [pcs/year] for planning period should be greater than the upper bound $\overline{U}$ desirable.

$$\zeta_i \geq \overline{U} \quad (7)$$

(Available Production Time) The amount presents the sum of processing hours for net shape of material *NS(m)*, production hours, and recycling hours for disassembly, *DA* and re-processing, *RP* of the end-of-life products.

$$\sum_{i \in I} \gamma_i(NS\ (m)) + \gamma_i(p) + \gamma_i(DA + RP) \leq \Gamma$$

where Γ [hrs/year] means available production hours.

(Goal Constraints) A set of constraints that define deviational variables placed in the objective function can be expressed as follows:

[1] Production volume required for each part should be satisfied for a certain

manufacturing processes, namely,

$$\alpha_i q_i(p)\Gamma + n_i - p_i = (1-\zeta_i)Q \qquad (8)$$

where Q is production volume required, $q(p)$ means production rates in a manufacturing method p, α is number of a part required for making a product.

[2] Energy consumptions in material processing will be dependent on decision variables in terms of material, shape and its dimension. The consumptions must be less or equal to value AE_{im} calculated in the energy-optimizing life cycle assessment

$$E_i(m,h,d) + n_{i1} - p_{i1} = AE_{im} \qquad (9)$$

[3] Energy consumptions in manufacturing process, in the same manner, should be less or equal to AE_{ip} that express a value assessed at the manufacturing stage of product's life-cycle.

$$E_i(m,p,h,d) + n_{i2} - p_{i2} = AE_{ip} \qquad (10)$$

[4] Energy use in maintenance stage will be influenced by four situations: the product life length, frequency of preventive, breakdown and repair maintenance.

$$E_i(L,M(f);m,p,h,d) + n_{i3} - p_{i3} = AE_{ia} \qquad (11)$$

[5] Energy use in recycling stage of product's life-cycle can be estimated by transporting energy for recycling collection, disassembly, re-processing.

$$E_i(te,da,rp;m,p,h,d) + n_{i4} - p_{i4} = AE_{ir} \qquad (12)$$

(Objective Function) The criterion for optimizing the life-cycle decisions of less energy-intensive material and its net shape, manufacturing method, maintenance strategies and recycling plan is to minimize the total energy consumptions throughout the whole life-cycle of product. The deviations from five goals are minimized in the following objective:

$$Min \quad (p_i,\ p_{i<1>}, p_{i<2>}, p_{i<3>}, p_{i<4>}) \qquad (13)$$

where < > expresses ranking of goals in the descending order of the value *AE* obtained from life-cycle assessment.

3. Developing Server-Side Web Application

A highly extensible and flexible server-side Java application may be advantageous to share all environmental data and various products information between manufacture and supplier throughout the entire life-cycle of product in a cost-effective timely manner. The Web-based cooperative method is helpful to improve current material circulation along with an excellent solution satisfying several requirements, such as high recyclable low-impact on the environment, lighter and less energy-intensive, as well as high manufacturability, simultaneously.

The effectiveness of dynamic Web server application has the following features:

- Knowledge sharing of a variety of product data and its environmental data in a JIT manner,
- Real-time collecting environmental data and real-time status monitoring of material flow in the entire life-cycle of product,
- Continuous improvement of life-cycle decisions.

3.1 Prototyping Systems

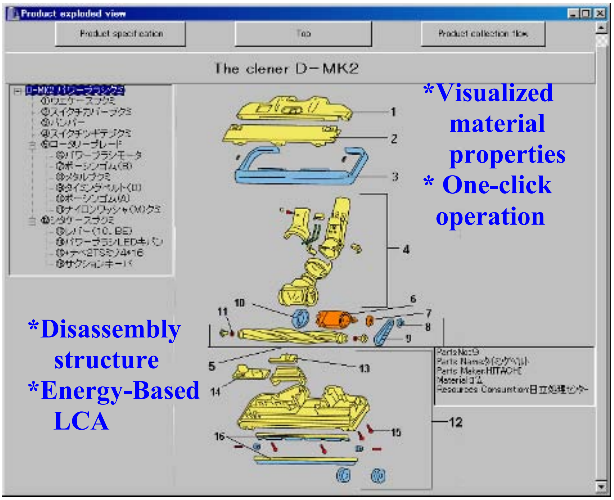

Figure 3 Java-Based Prototype Systems

These components including visual tools and wizards are developed rapidly by Borland JBuilder software supporting pure Java development. A Java-based prototype system that was developed on Windows PC platform is illustrated in Figure 3.

3.2 Continuous Improvement of Life-Cycle Decisions

Products must be continuously improved to compete successfully in today's highly competitive markets, as well as being achieved excellence in environment preserving. Ironically, product variety and shorter life cycles of modern products dramatically increase the complexity of the tasks of product design and process design. Due to difficulty in processing information and solving unstructured problems, it is usually impossible for designers to consider knowledge of all possible combinations between materials and manufacturing methods. The continuous improvement life-cycle decisions, combining life-cycle design and manufacturing as well as product maintenance and recycling decision, strives for aiding continual and rapid improvement in quality, cost, lead time, and customer service while achieving superior environmental performances.

The superior approach is computationally efficient and leads to a quick solution through the human decision-making process, which is often required in a constantly changing manufacturing system. The sophisticated methods are continual and rapid improvement in quality, cost, lead-time, and environmental impact while achieving superior recycling performances.

The overall feature is shown in Figure 4. The key to continuously support recycling activities and product development lies in combining and coordinating two following significant features: (1) functionally and environmentally best product design for aiding environmentally safe material and manufacturing process selection and (2) an intelligent decision support system to evaluate periodic performance of recycling-conscious planning and material flow status.

The intelligent decision support system operates through the repetition of the following five sequential functions [6]: real time status monitoring, trend and/or

forecast modeling, diagnosis, simulation optimization [7], and periodic evaluation.

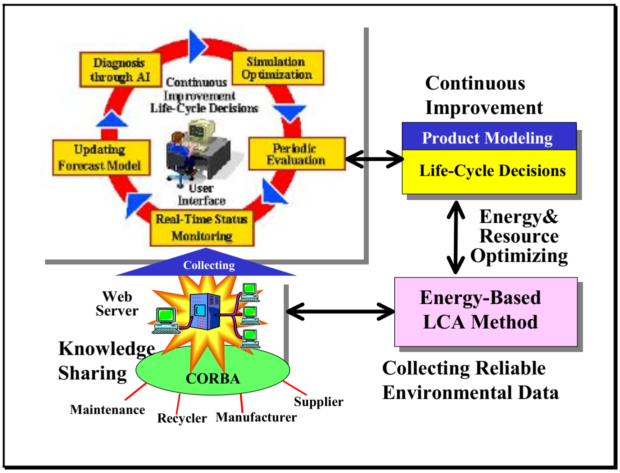

Figure 4 Continuous Improvement of Life-Cycle Decisions

- Real time status monitoring. It offers adequately the activities of monitoring the progress of production and the actual material flow through the entire life-cycle of product in terms of current status on production facilities, all parts of product, materials, manufacturing process, stock level of each part or unit, recycling process, history of maintenance, recent performance of material flow, scheduling and so on. All of these data items have to be collected in real time.
- Trend and/or forecast modeling. Automated data analysis and acquisition from corporate-wide operating activities would be required to ensure that the status of all entities of material flow and production was updated continuously. A wide variety of real data has to be analyzed and compared in order to update current forecast model and improve life-cycle modeling through neural network techniques.
- Diagnosis through AI. The purpose of diagnosis is to support the user in determining the cause and potential solutions to problems or events detected by monitoring. The diagnosis module has a function to accumulate a store of knowledge concerning how best to overcome contingencies in the forms of re-scheduling and re-allocating production facilities and resources. A more effective and quicker processing of the contingencies results from interfacing the user and the problem-solving mechanism.
- Simulation optimization. It is responsible for synchronizing recycling-conscious production management decision and manufacturing technologies. The major function of simulation optimization is to support the user in determining possible corrective actions and potential solutions to purchase-order release by considering recovery and recycling status of end-of-life products. The alternative plans will be examined by using various simulation parameters changed through the user interface. The simulation parameters can be altered and divided into several categories at each dispatching rule.
- Periodic evaluation. Results evaluation and performance measurement are needed to ensure or predict the consequences of implementation of suggested potential

solutions. Consequence evaluations create the basis for selecting the best solution, and are to evaluate the actual and simulated performance of the material flow. Periodic performance of recycling-conscious decision measures from the simulation optimization techniques with the various criteria, and is compared to threshold value with specification of upper and lower limits. Periodic evaluation of recent performance is significant for continuous improvement of material flow and recycling activities.

4. Conclusions

A Java-based Web application was developed to enhance and further a recycling-conscious activities and material flows in the entire life-cycle of product. The highly extensible and adaptive server-side Web application, which aims to more energy-effective and environmentally best life-cycle decision, is mainly concerned with efficient integration of four functions. Firstly, an energy-optimizing life-cycle assessment was developed for selecting environmentally sound materials and manufacturing process through weighted normalizing procedure between various environmental impact criteria. Secondly, optimizing life-cycle decisions were discussed to guarantee environmentally preferable material and its net shape, less energy-intensive manufacturing process in a better way of minimizing environmental impacts and energy consumption through the entire life-cycle of product. Thirdly, Java-based Web application was elaborated not only to share knowledge of a variety of product data and its environmental data in a JIT manner but also to collect environmental data of real-time material flow status. Finally, continuous improvement of life-cycle decisions was addressed to compete successfully in today's highly competitive markets, as well as being achieved excellence in environmental preserving. A Windows-based prototype system was developed by integrating JBuilder and AI programmable languages.

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Concurrent Engineering application on the development of parts for the White Goods industry in Brazil – a case study

João Pedro Buiarskey Kovalchuk
Electrolux do Brasil S/A. – Pontifícia Universidade Católica do Paraná (PUCPR).
Ministro Gabriel Passos St, 390 – Curitiba, PR – Brazil –
joao.p.kovalchuk@electrolux.com.br

Osíris Canciglieri Júnior
Pontifícia Universidade Católica do Paraná (PUCPR)
Imaculada Conceição St, 1155 – Curitiba, PR – Brazil – osiris.canciglieri@pucpr.br

Antonio Batocchio
Faculdade de Engenharia Mecânica FEM – Iniversidade Estadual de Campinas
UNICAMP – batocchi@fem.unicamp.br

Abstract: The classical way to manage product development processes for massive production seems to be changing: high pressure for cost reduction, higher quality standards, markets reaching for innovation lead to the necessity of new tools for development control. Into this, and learning from the automotive and aerospace industries factories from other segments are starting to understand and apply manufacturing and assembly oriented projects to ease the task of generate goods and from this obtain at least a part of the expected results. This paper is intended to demonstrate the applicability of the concepts of Concurrent Engineering and DFMA (*Design For Manufacturing and Assembly*) in the development of products and parts for the White Goods industry in Brazil (major appliances as refrigerators, cookers and washing machines), showing one case concerning the development and releasing of a component. Finally is demonstrated in a short term how was reached a solution that could provide cost savings and reduction on the time to delivery using those techniques.

Key Words: Concurrent Engineering, DFMA, Project Management, White Goods, development of plastic parts.

1. Introduction

Projects are been deployed faster and faster through time – cost reductions and conceptual changes with shorter time to go into the market are now the way to work in almost any industry – mainly in the White Goods (major home appliances as refrigerators, cookers and washing machines): pressure caused by competent and strong players, reduction in the markets and a costumer that demands more per money is the daily reality. For those highly aggressive conditions, more suitable ways to manage product and component developing to fit the necessities are now more needed than ever.

To match those, and using the example from the aircraft and automotive industries, the DFMA and the Concurrent Engineering show themselves as powerful alternatives to the running design management methods, bringing together some interesting advantages. About those, BOOTHROYD (2001) has affirmed that a winning project can only be developed when the product responsible is prepared to get in to the process and understand the way the manufacturing works and behaves – something close to what HUANG (1996) stated about the good developer, who "must know the manufacturing to prevent unrealizable products due lack of intimacy with the productive process". Agreeing and complementing, according to DEWHURST (2005) project must involve any single part and respect all opinions; else, the lack of participation of one or more groups can mitigate the success of the product and finally, increase unexpected costs and problems.

All them are showing a well known panorama – a project must be accepted and discussed with all responsible: the design area, which is the conceiver of the product, then the project engineering, which will transform the sketched concept into a proposal; after the process engineering that will prepare the factory for the project; forwardly the manufacturing which will release the concept into a tangible product, the quality people that approve the developed parts and processes and so on.

Over that, this paper intends to show a successful product developed under this synergy and also explains how Concurrent Engineering and DFMA have helped teams to reach the target of develop a new part more affordable, with quality improvements, reduced time to assembly and with a short time to enter the market.

2. Research Methodology

Regarding to the research method, this can be an explanatory case study – according to TELLIS (1997) – this kind of cases can use pattern-matching techniques and conduct a study to examine the reason why some research findings get into practical use. They used a funded research project as the unit of analysis, where the topic was constant but the design varied (YIN and MOORE (1988) *apud* TELLIS (1997)).

Since that and based on observations, studies, tests and some literature revision and research an opportunity for application of DFMA and CE was identified and a solution was proposed: the research was divided in phases, driven by events and milestones. Firstly there was the identification of a project that could offer an improvement possibility. Discussions over the deficiency of the recent management methods and practices applied in the design/manufacture/assembly took place based on the literature and cases observation. After that, opportunities to the develop a new part using DFMA and CE methods and concepts were raised and the real application was chosen to be used as a demonstrative example. In the second phase, these methods were presented emphasizing the process and controlling activities. In the subsequent phase the

conceptual project was carried out as a product and in details about the proposed methods were given, to share information to support the multiple viewpoints. A detailed view of this process, including sub-phases and milestones can be seen in Table 1.

Project Phase	Process	Expected Output
Conceptual phase	Beginning of a new project	New opportunities are researched
	Opportunities analysis	Alternative concepts
	Product definition and concepts	Product initial aspect and preview
	Strategy and tactical startup	Project and process proposal
	Presentation for approval (Directory, CEO...)	Permission to continue
Exequibility phase	Studies of planning, research and exequibility for	Corporative acceptance criteria
	Functional specs and characteristics improvement	Project briefing
	Development of a project-product basic specs and	Project palling and resource planning
	Project final approval and resource+investments	Project approval
Implementation phase	Multidisciplinary specialists team reunion and task spreadment	Work functions - responsibility matrix
	Concept closing and product candidates choosing	Preferred option
	Project contour and lay-out arrangement	Product solving
	Detailed product project	Full detailed product specs
	Prototypes and tests for large scale production phase / manufacturing full project issuing / manufacturing test and launching support	Performance and manufacturability confirmation
	Supply chain and logistics budgeting	Parts or resources ready to the manufacture
	Product show-up	Product availability

Table 1: Project milestones

Adapted from MARSHALL (1997)

3. Concurrent Engineering and DFMA

According to ARAÚJO (2000) *apud* CANCIGLIERI (2005) communication and information share is important to all design definition and execution phases, but mainly in the conceptual phase. That viewpoint can be defended when is considered the aggregated cost caused by any late change needed by misinformation, an unexpected redesign or reprocess or either a necessity that was neglected due lack of a strong team participation – ANDERSON (1990) *apud* CANCIGLIERI (2005) evidenced this by affirming that the design determinates the product manufacturability and a significant part of the resources investment (80%) - once these resources have been allocated, it will be very difficult and expensive to make any changes, as shown in Figure 1.

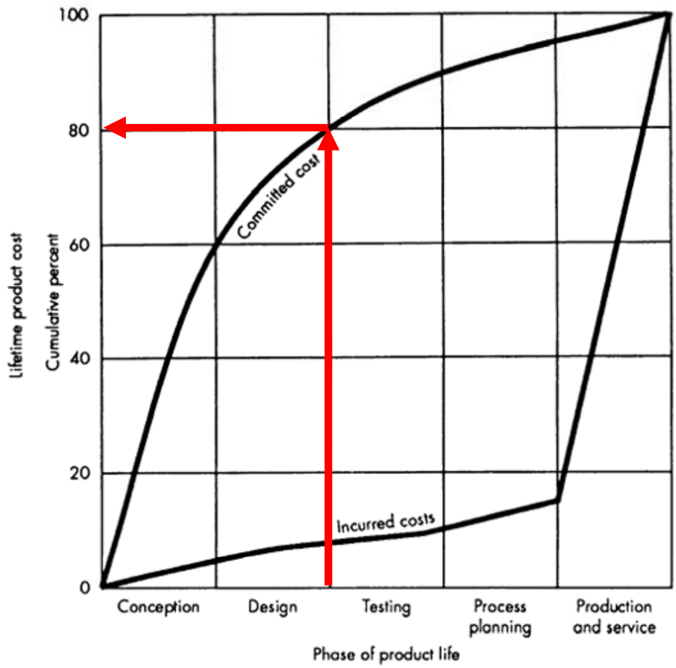

Figure 1: Development costs – process and product

Adapted from: ANDERSON, 1990 *apud* CANCIGLIERI (2005)

All information leads only to one abstract: it is strongly necessary to keep in mind that any product and its generation process must be well evaluated from the beginning and most of opinions (if possible all of them) have to be considered before the project reach the exequebility phase.

3.1 Concurrent Engineering and DFMA *versus* Traditional Design

Starting a new project has most of the times several inconveniences: CAPUCHO *et al* (1997) expressed this saying that generally a project starts some problems caused by misinterpretation of the available data (or low precision, of even complete lack of information) an that could extends to subsequent steps of the project. Also, imprecise communications between involved parts could cause undesirable effects. Those must be added also to other limitations – machine restrictions, low investments, schedules, space and logistics.

That means a conceptual challenge: how to develop a new product trying to find the best cost-effectivity in the shortest time, hearing all different opinions without loosing the acquired knowledge about processes and also fitting the consumer necessity?

The design will determinate the manufacturability of a product, not the manufacture by itself – even considered a very high sophisticated one. In fact, this level of

sophistication (maybe considered also as automatization) will reinforce the necessity of a well-elaborated project (CANCIGLIERI (2005)).

Traditionally a productive process has some basic steps (GALDAMÉZ, 2001) – first, the identification of customer needings and desires as a input, last a output represented by product or service to match as most as possible the needing expressed in the input and between them a productive transformation process feeded by information, resources (as materials and machinery) and a demand caused by a possible market as showed in Figure 2.

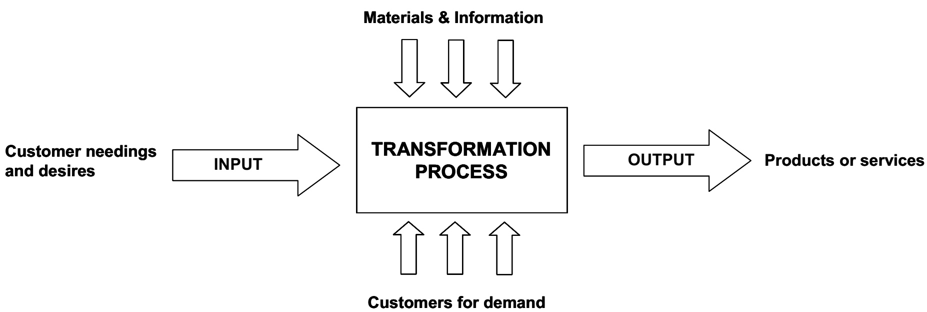

Figure 2: Model of a generic process or productive system

Adapted from: Galdaméz (2001)

However, this kind of simple interpretation seems to not consider the information flows from the process to the input and output – information which can show some limitations or can express the necessity of change or improvement: modern White Goods factories use to work simultaneously with several products in one assembly same line and not rarely a part or component must be used with the same application conditions to different platforms. Also, most of the known players do stepped investments and some products are just upgrades of their predecessors, not completely new developments. Finally, it is necessary to maintain (at least for some years) an assembly line, method and machinery to ensure spare parts to the working population of products.

Those apparent undesirable conditions may present a very good opportunity to rethink the development process: experience obtained from previous projects and the knowledge of where are the weakest points can reveal a path to start a production oriented design methodology over them.

3.2 Concurrent Engineering: WHY?

Organizations learn in order to improve their adaptability and efficiency during times of change BRINK (2003). This idea can effort the use of the experience of previously done mistakes to speed up the development process and also accomplish new

technologies and philosophies to ensure that activities which now must be faster and give more precise results can really reach this target.

In this way, DFMA and CE (both production oriented designs "ways") offer a substantial advantage: they permit to run activities simultaneously in a parallel form, in opposition of the tasks sequencing. Also, they allow using simulation techniques and a full synergy between the teams – these make possible to find project failures or deviations and fix them before the development ends – FERNEDA (1999), as illustrated in Figures 3a-b.

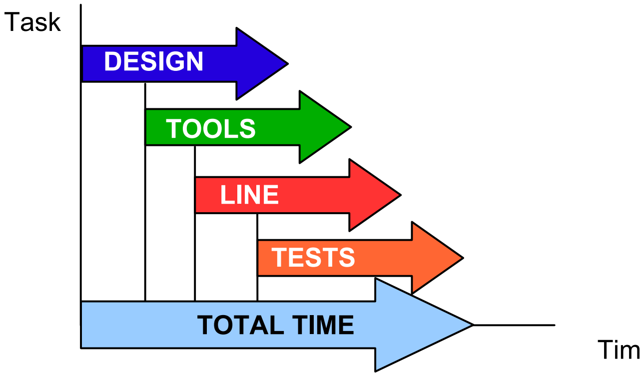

Figure 3a: Tasks concomitance using the Concurrent Engineering

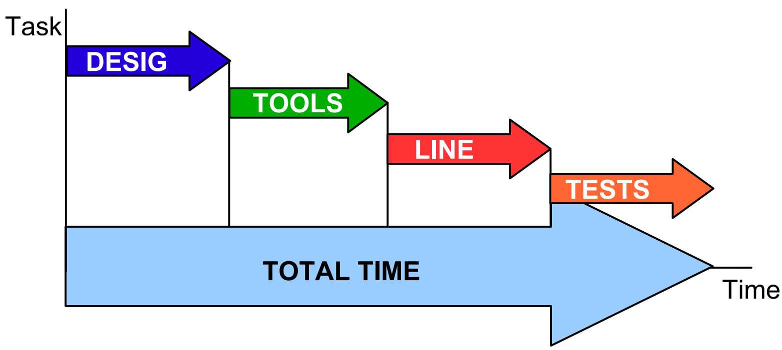

Figure 3b: Tasks sequence using the traditional management methods

Bringing to the White Goods industry reality, DFMA and CE permit develop faster, with savings (time, money, work) and mainly with a higher level of hitting the quality levels and the production standards through an assertive development management way: seems to be clear why to use the resources of a production oriented design – but how to do this?

3.3 Production Oriented Design using CE and DFMA: HOW?

Designers do not enter a new design situation as newcomers or novices. Through education and practice they have acquired a vast repertoire of design solutions, which they will carry over the design task at hand (PASMAN, 2003). These experiences are

the result of several situations of mistake, improvement opportunities or just real good new ideas acquired due to development and research on design area.

But how to acquire a "high manufacturability level product" experience? HUANG (1996) affirmed that reasons like increasing complexity level of the bundled technologies in the product, stress caused by short time to deliver some output to the market, the pernicious philosophy adopted by some designers of "we design, you assemble" or "we do sketches, you do products", the complexity of some industrial processes (and sometimes even the distances) invalidate the simple idea of the development people caring about the manufacturing reality.

A good development designer/engineer must know the factory in a sufficient detail level that can permit an assemble to be done and an injected part to be extracted and also must know his job to ensure the assembled parts to be there and the injected material to be in the correct geometry. These means two different and in a first view conflicting conditions: that the designer cannot stay in his area ignoring what is happening around and the designer must know his tasks perfectly to justify his work position.

The question remains: is it possible to be in simultaneously in the factory and in the design office? FERREIRA and TOLEDO (2002) say so and suggested how: using the technique of Design for Manufacture and Assembly is possible to "hear the voice of the production line" and been virtually near to the information. BUSS *et al* (2001) agreed with this point of view, saying that the DFMA and CE allows bring to the project area the considerations related to the assembly and manufacturability of the product. Finally FAGADE and KAZMER (1998) defended that the most significant advantage of DFMA is the encouragement of the teamwork between project and production, improving the reliability of the final product and generating the possibility of cost/time to deliver reductions due decreasing in the parts number and/or more productive parts that can accelerate processes.

Now the perspective is clearer: is understood why use a production oriented design and how implement this using the CE plus DFMA. The next step is clarifying what to do to "have" them.

3.4 CE and DFMA: WHAT?

First of all is necessary to understand well what is needed to drive a project with Concurrent Engineering techniques. For this is important to define the product conception as a task of multiple responsibility: since the first conceptual sketch to the final packed assembled delivered product many are the necessities and interdisciplinary actions that are needed. CANCIGLIERI (2003) and PERERA *apud* SACCHELI (2005) mentioned that in a multiple viewpoint manufacturing and project system all opinions must be considered interdependent as shows figure 4. Thus, the accordance over key points must be decided in intelligible form that can allow all the productive chain to express its necessities and limitations in a clear form to any other part connected to it and responsible to provide or receive services/preprocesses.

Also is essential to let all teams warned that the project is designed for manufacture and assembly – and this means that all attention is focused in a development for that condition and this means that the manufacture must be heard all time. Process times, workers number, tools for assembly, in-line stocks and other typical variables emerged from the shopfloor are vital for the development and other variables must express themselves as factory improvements or assistances.

To achieve this the communication has to be constant and efficient: information sharing/translating and data optimization are basic requirements on a CE driven development.

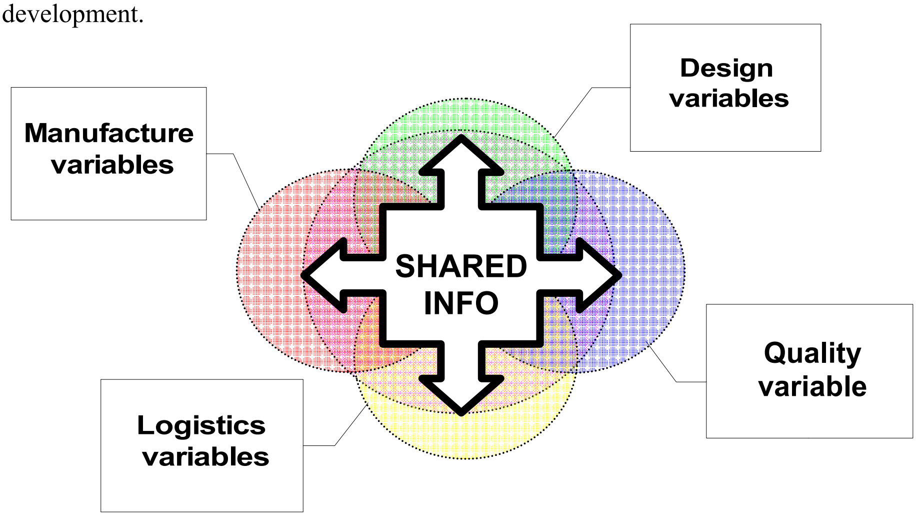

Figure 4: Interdependence of variables (opinions) for a DFMA driven development

The sharing of information has its own reason: system variables are quite complex when analyzed locally, but once put together are virtually different forms to observe the same necessities. As an example of it is the task of reduce man work to save costs – one suggestion to do this is simplify the assembly by decreasing the number of parts. For the manufacturing specialist it's a time and work save – the task is accomplished. However, for the logistics this means fewer parts to administrate and for the quality less components to present a failure – all these outputs are inputs to the project designer who must think on a compact multifunctional part – but all of them are generated by the necessity of save costs in the assembly posts.

Finally: to follow a project development processes with production oriented design concepts in vital to have a solid knowledge of the factory limitations and processes – that is the information sharing and teamwork are for. No CE nor DFMA concept can be applied of a unknown or not well-known productive plant or in a unclear productive process. Once information is common to everybody and all have in mind their tasks the last question can be seen: when is time to take actions to boost the development with the Concurrent Engineering?

3.5 Concurrent Engineering: WHEN?

The last part of development with CE plus DFMA techniques rest on the time management. According to Table 1 and figure 3a activities run together in a project. But when is time to carry over a new task?

Answering this question CAPUCHO *et al* (1997) adopted after observe the behavior of multidisciplinary teams that the local rework caused by an activity with

adverse results is much smaller then a global restructuring of a project – also, a global reproject may be impossible due costs (according to HARTLEY and OKAMOTO (1992)) the inclusion of a change in a running project is more expansive as more is close to the project end or due other factors as time and market expectations.

So, once defined the project main activities and tasks start doing them is a good option, respected the order of the development – as mentioned before mistaken actions and adverse results can less compromise the project running timetable and budget as first they are identified.

4. DFMA and CE in the White Goods industry – a case study

Applying the concepts of DFMA and CE to a new part development, a local Brazilian White Goods industry could illustrate the advantages of a multidisciplinary part development. The task was substitute a complex assembly of different parts made of press worked metal and plastics by a aggregated function single solution with cost reduction, short-time tooling payback, quality improvement and mainly ease to assemble in line.

4.1 Which technology?

According to BOOTHROYD (2001) the rising sophistication in the use of molded injection plastics is an important tool to win the battle of reduce parts to save costs and create an elegant design.

Also, BEALL (1997) said that plastic injected parts could consolidate several different other parts – plastics or not – in a complex geometry what can be obtained in an injection process with relative ease and with this save sub-assemblies and mounting operations. Finally, GAUTHIER *et al.* (2000) shown that is possible not only find saving using plastic multifunctional parts, but also improve the general quality of the product by reducing the probability of defective parts in the assemblies and the possibility of a mistaken coupling.

Based on the literature mentioned and other articles researched by the groups and considering the expertise of the teams on plastic injection acquired by work and development in other lines (refrigerators and washing machines), where plastics are used in a very large scale, was decided to try a solution using injection of thermoplastics.

This was a risky decision: first of all the temperature limitations on a plastic material are more severe than in a press worked metal – limits also include the possibility of deformations, flowing and resistance downgrade. After that, a running and deployed solution give some comfort to the project designers and all of other teams: the new idea was offering a possibility of assembly improvement and a bundled possibility of fail – this means that for some parts of the workgroup the manufacturability advantages were not good enough to release the change – in short words that was the paradigm: develop a substitute part to improve a good working assembly to give some help to line and to reduce costs, with a low, but existent, possibility of further problem.

4.2 The substituted assembly

The original assembly composed of plastic parts and pressworked (figure 5) metal lead to nineteen attaching, two riveting and one screwing sequential operations - the

assembly condition demanded two working positions and needed specific equipment and care. Also, the attaching manipulation was fully manual and highly sensible to errors due the complexity of join together all parts in a moving line. Finally, the riveting operation had its own difficulty – in the case of an imprecise attachment, the rivets could not be placed properly causing an off-line rework call and stopping the production flux.

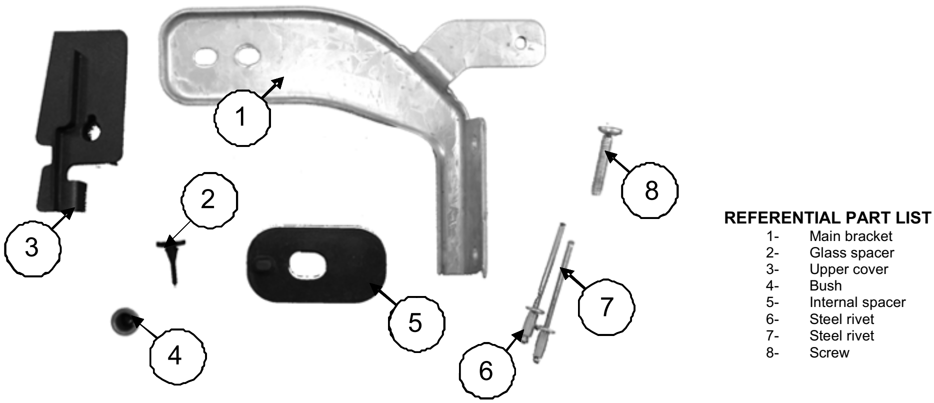

Figure 5: Original assembly

To avoid these inconveniences and fit the high level of reliability required, a new injected component was designed to aggregate in an single plastic construction the maximum as possible original single parts and a error free mounting.

This component was conceived under the DFMA+CE philosophy and was expected to result in one high manufacturability development made from a productive low cost heavy duty material and projected to join six other components resulting in the maximum possible exclusion of intermediate operations.

The multifunctional part was able to permit the exclusion of seventeen of the original nineteen attaching operations and took out one of the riveting tasks due the substitution of one rivet by a pivot (figure 6, item 6) directly emergent by the structure of the multifunctional part. This pivot, which is normal to the foundation of the part, was projected to be one partial anchorage and lock to the structure, ensuring the right placement of the whole assembly.

Another anchorage is offered by the upper cover (figure 6, item 3) 90° cross-phased from the pivot and grooved to fit the construction of the column where the part is mounted on which by its geometry reduce to almost zero the possibility of a wrong assembly. Finally the bush (figure 6, item 4) is also 90° cross-phased from the other two attachments, ensuring the full locking of the component to the environmental geometry, causing a full compliant assembly even when the other components (not treated by this development) present variations out of the tolerance levels.

All these and the extreme easiness to produce an injected part this means 80% reduction in the assembly and 15% reduction in the composition of costs, and a short term payback of the injection mould.

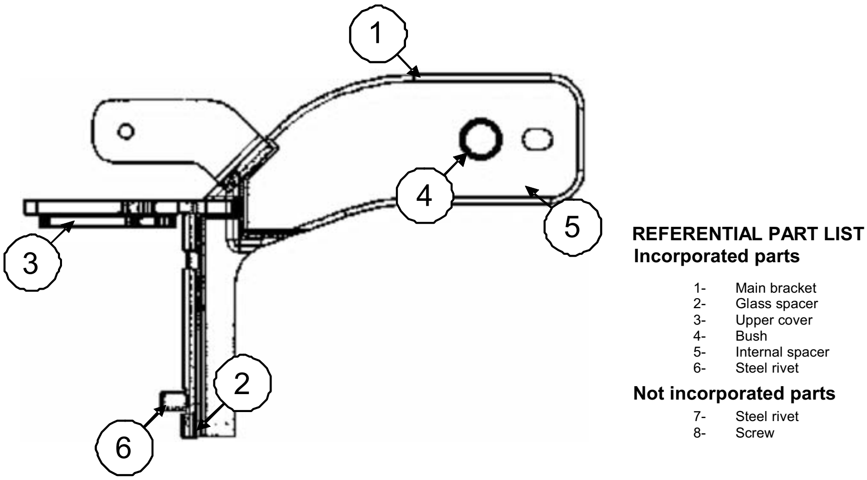

Figure 6: New part design

Figure 7: New part photo

5. Discussion and Conclusion

In this article has shown an application for the concepts of DFMA inserted in a Concurrent Engineering collaborative context for the development of a new part for the white goods industry (home appliances) focused in low-cost, high manufacturability, long-term reliability and resistance to severe working duty. The article presented either some guidelines for development using in DFMA and Concurrent Engineering, based in the industry-level bibliography. Also, was shown the application in the steps of the development since from the conceptual idea to the final implemented project. Finally were presented advantages that can justify substantial savings of time and cost in the

development of high manufacturability products when using DFMA and the CE methodologies as production-oriented guidelines.

As could be justified, the development of a new part in any industry (mainly in the analyzed case of the white goods industry) speeds up substantially when working in a collaborative-concurrent engineering environment – when teams work together and simultaneously the results of the development can be faster and furthermore, cheaper. Using the Concurrent Engineering as the main guideline, in addition with DFMA as methodology of work, results can be presented faster and with increases in the level of control, investment application and rightfulness.

Concerning the development of the part, the value added by DFMA and CE was also very important: more than only the development process, the part itself needed special care due its own special heavy-duty working environment – have reliability of a structural part came from the steel and passed to plastics is delicate, mainly when high temperature and aggressive humidity, chemical and use collaborates in the mechanical stress of the part. There, in the concept of the part and the using position DFMA and CE where specially useful because they permitted a better communication between all involved teams and this philosophy helped in pass from the Product Engineering the product conditions to the Industrial Engineering that developed the tooling and the Manufacturing Area, that was warned exactly about what expect from the part.

That was decisively important: the advantages of this communication could save time - the mould was made as expected by the product developers and manufacturing people have determined, avoiding rework. Furthermore, saved money – the part was designed more then one time, but the final component only was made once – this was money saving in prototypes, tests and working time. Finally, the component was designed for the production line – fewer parts and assembly-line speeders as fast locks, pins in place of rivets or screws, pre-assembled features, self-positioning parts and adaptable robust-design made more productive teams, saving money. Also, fewer parts finally decreased 15% the whole assembly cost directly in the materials prices – with the advantage of logistics, shop-floor space and avoiding sourcing from more than one supplier.

In the last, the main advantage was the application of a newer way to work – working in teams that can do engineering concurrently and designing for the last part of the production chain results were sensively more precise and most of the time, faster and cheaper.

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Methods and Tools to Support the Cooperative Design of One-of-a-Kind Products

Dieter H. Mueller, Heiko Gsell, Nils Homburg

Abstract

To cope with the strong world-wide economic competition one-of-a-kind products are being designed cooperatively by former competitors to optimize the utilization of individual capacities. This trend is combined with a close integration of system suppliers into the early design process. Establishing a continuous workflow between these partners demands a highly flexible network for conception, design and production. In order to set up this network cooperation between the partners a flexible product data structure through which work packages containing design tasks can be exchanged and executed in different CAx systems has to be available. Supporting the exchange this is to be combined with a suitable communication structure hosted by a communication platform. The paper at hand describes an approach for the exchange of product data, which integrates a structural view to the design process as well as a work package structure represented through XML documents forming a practical product data model. The work packages are formed by predefined data objects representing particular product views which are relevant for the individual design task. This new type of cooperation is show at the example of the German shipbuilding industry and their main system suppliers.

Keywords: cooperative design, product data exchange, key attributes, general cooperation model

1 Introduction

One-of-a-kind products like ships need an intensive cooperation of different actors (ship builders as well as suppliers) working in highly flexible networks to cope with the often changing project constellations. To establish a network cooperation between these partners a flexible product data model is needed that allows a speedy and easy data exchange between the partners. New methods and processes are necessary to successfully cooperate in these projects especially in the early stages of the design process. For the data exchange a suitable communication structure hosted by a communication platform is needed. An easy orientation within the product data model can be realized through designer orientated views on the product data structure. This is represented through room as well as system centric views orientated at the individual tasks of the designers.

2 Initial Situation

An intensive cooperation of all partners involved in a shipbuilding project is true for all phases of such a project – from conception through design to production of the ship. Normally, project constellations are subjected to change during ongoing projects where in different phases new partners have to be integrated. Even greater changes occur if a completely new project for engineering and producing of a new ship is set up. To get a dynamic network cooperation between these partners working there is a need for an easy to handle information and communication structure through which work packages containing construction and design tasks can be exchanged. From a PDM point of view a main challenge during designing and producing a ship which usually is a one-off product is building up a

manageable structure of the ship's product data. The built up product data model must support a speedy and easy data exchange between the network partners and, in particular, it must support a traceable revisionary management which in shipbuilding projects in difference to most other engineering tasks is very hard to manage. Consequently, there is a need for defining the technical requirements concerning the identification of a ship's component parts when product data between different partners are exchanged as well as for an ideal product data model for shipbuilding industry which supports the data exchange.

The existing complexity of ships needs a cooperation between the shipbuilders and their sub-suppliers. Changes of one of the design parts will create necessary changes of many of the sub-suppliers. On the other hand it is necessary to create a first data set immediately after start of the project. This conflict can only be solved by using innovative methods to describe the cooperation between the partners. One of the most important projects researching these topics is the so-called NET-S project (www.net-s.org), where research institutes as well as ship-yards and suppliers for the shipbuilding industry participated in defining suitable attributes for identifying the complete ship [1]. In addition, within this project an information and communication platform for product data exchange between partners working together in cooperative shipbuilding projects on an equal level (core partners which today mainly are shipyards) as well as between different levelled partners (e.g. shipyards and suppliers) is built up [2].

3 Research Approach

To find out the attributes suitable for identifying a ship's component parts in a first step the existing identification systems of two shipyards were analysed. Starting from this, in a second step a classification of the attributes was carried out that allowed an estimation which of the attributes can be used for an explicit identification of a ship's component part. These attributes were continued to be differentiated so that only a few attributes remain to be useful for identifying a ship's component parts (cf. figure 1).

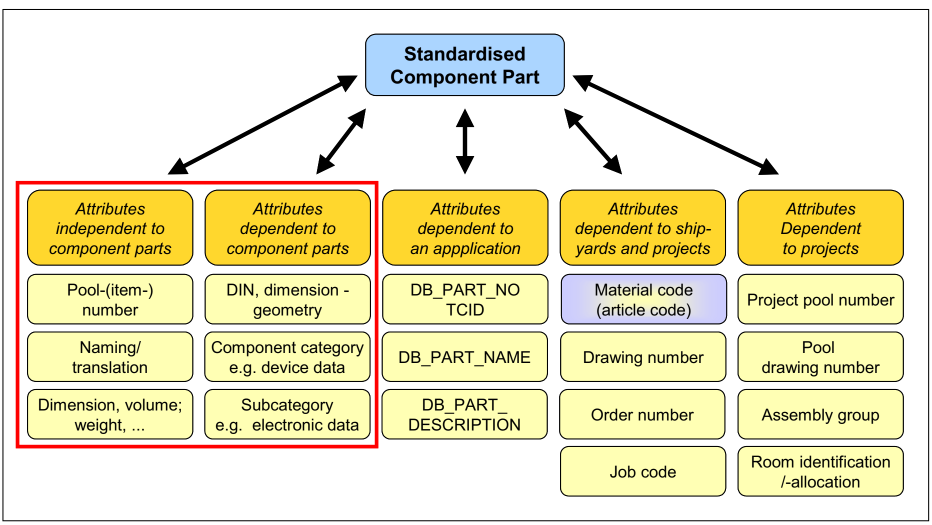

Figure 1. Attributes for identifying a ship's component part

For the development of the product data model the interrelations of these ship's component parts were analysed and represented in entity relationship models [3, 4]. These models support the derivation of exactly these views on a product that are necessary for solving a specific problem or for performing a specific task. The conceptual advisements in combination with the needs and requirements of the industrial partners finally lead to a few attributes that would be used for identifying the component parts when product data are exchanged between the partners of a shipbuilding project. These defined core attributes for identifying ship component parts in combination with the needs and requirements of the industrial companies participating in shipbuilding projects lead to these attributes which are now being used for the exchange of product data within the NET-S consortium. Some key attributes for identifying ship component parts are (a) the ***name/notation*** of the part, (b) the ***cross-company ID-number*** which gets assigned through the communication platform and (c) the basic metrics like ***dimensions, volume and weight***. Further more, there should be a reference connecting these attributes to documents giving some additional information about the part.

Taking into account the identified needs and experiences of shipyards and supplying partners working together in a shipbuilding project in a further step a general cooperation model for shipbuilding with different views to the product data has been developed. Further more, the design results relevant within a shipbuilding project have to be available in a structured and clearly defined model and enable views to the data that supports the design methods of all participating parties. To meet these requirements, the developed cooperation model represents a ship in its state of delivery in different views. For the model the NET-S project [1] has chosen two prime views on the ship's design data which are on the one hand the so called "room view" and on the other hand the view on the ship's systems. These views on the ship give the opportunity to establish a task orientated design environment which is needed to solve a specific problem or to carry out a specific task.

4 Findings

The combination of the key attributes for identifying a ship's component part with the conceived general cooperation model for shipbuilding and its different views lead to a total of 13 data objects that are necessary for defining the work packages exchanged between the partners of a cooperative shipbuilding project. The basic attributes valid for every of the defined objects are a identification number, the name of the object, the object description and a values list. The 13 defined objects form a hierarchical structure to organise the product data of the work packages to be exchanged between the shipbuilding partners in a well manageable manner. Figure 2 shows the correlations between the specific data objects relevant to establish the "room view".

The arrangement of the objects allows a delimited view of the cooperation model that exactly provides the room in which a task has to be fulfilled. To assign a task within a specific room to a design office or a system supplier a work package has to be created that is being exchanged between the partners involved through an information and communication platform. On the basis of the 13 defined data objects that are necessary for defining the work packages exchanged between the partners of a cooperative shipbuilding project and of the conceived general cooperation model for shipbuilding with its different views a number of exchange scenarios were set up to test the product data model. The exchange of the product data through the information and communication platform is described in the following paragraph. Basis for an exchange of defined product data is a XML scheme also shown in the

following paragraph which checks for the correct layout structure of the exchanged product data arranged in the respective work package.

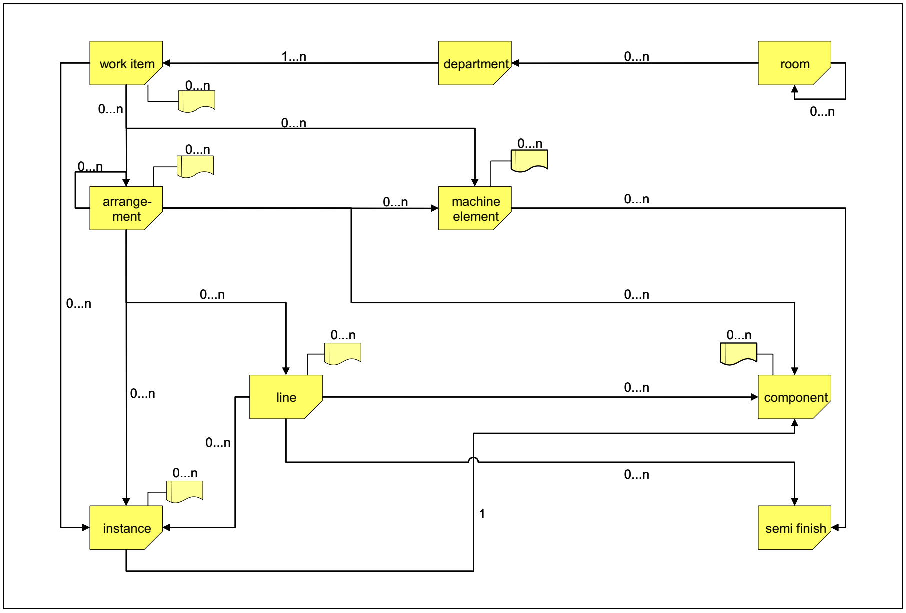

Figure 2. Assignment of the objects

Concerning the product data model the partners of the NET-S project detected the necessity of two different views on the ship's product data which are on the one hand a so called "room view" and on the other hand a view on the ship's systems. The room view structures the ship by dividing it into physical rooms as well as into technical rooms, which may completely differ from the physical rooms of the ship. It derives from the following two design elements: (a) the ***hull*** of the ship and (b) the ***main dimensions*** which are decks and important vertical zonings. The hull of the ship is represented by the ship's body which is created by a planar model. The definition of the planar model is realised by the NAPA system usually used by shipyards for 2-D construction. The generation of the body is realised by a CAD system to which the planar model has been transferred before. The main dimensions are defined by a grid which is valid for all persons involved in the construction process. Higher-ranking rooms, e.g. coordination areas, zones or panels are derived from this grid. By combining the hull and the main dimensions the concept model is created as a basis for the following segmentation of the rooms. By "cutting" the body along the main dimensions and the room zoning working areas could be created which are necessary for construction.

The room view of the ship's cooperation model is mainly needed by shipyards to create complete ship units and to define work packages which can be given to engineering companies or suppliers for further elaboration. It presents a basic model for structuring a ship. To exchange data concerning this view the component parts or artefacts to be exchanged are described as data objects. Further more, the built work packages could include structures and arrangements. How a particular work package is integrated into the design environment of the engineering companies and suppliers is decided by themselves. Only the constraints of the work package must be checked to ensure a defined exchanged of the product model data. The results of the elaboration are returned to the principal in a similar work package only

containing the results of the elaboration but none of the unchanged data from the original work package. The content covers all of the design results.

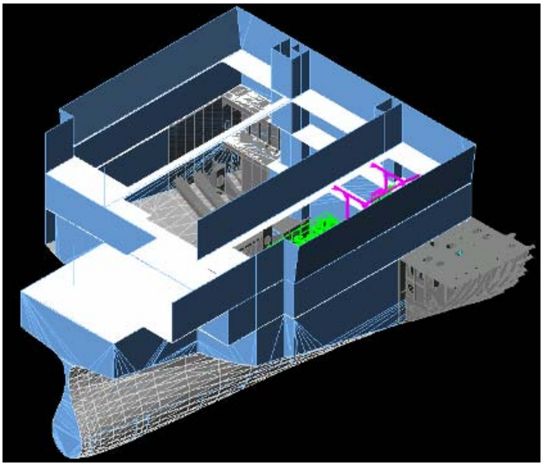

Figure 3. Room view on a Ship's basic model

Besides the room view a system view for the ship was developed which is especially relevant for the definition of systems by the systems suppliers. It allows a representation of the ship's systems independently from the ship itself. Within this view the ship's component parts can be classified along the systems of a ship like fuels, ventilation, power supply, equipment, etc. The system view allocates a defined structure for data exchange but does not define a generalised system view for all partners of a cooperative shipbuilding project. To create the view on the ship's systems an assembly unit directory is used which gives a unique filing structure for all parties involved in a shipbuilding project. This structure supports the exchange of product data and reduces the time of searching specific parts of a ship's systems. It has to built up individually by every partner of a shipbuilding project who needs a system view for his own work.

The implementation of the structure described needs a hierarchical organisation: Directly beneath the root directory of the ship are the directories of the room view and the system view. The directories within the room view directory show the underlying segmentation of the ship (prow, stern, deck, etc.). Lower in this structure there are the directories of the single rooms (e.g. engine room) which are structured along the categories engineering, facilities, coordination and equipment. Within the system view there are directories for the single technical systems (fuels, ventilation, power supply, etc.). Beyond this information concerning devices, configurations and foundations is filed. The connection between system view and room view can be realised by allocating a system to a room.

5 Product Data Exchange

If the work packages exchanged between the partners of a shipbuilding project do not follow the structure demanded by the room view of the cooperation model a correct transmission of the product data can not be secured. To make sure that no incorrect structured product data gets into the information and communication platform an XML scheme was developed that screens the layout structure of the XML documents being exchanged. This XML scheme

serves as a supervision system preventing the information and communication platform from accepting documents with product data structures that diverge from the defined work package structure. The XML scheme scans the composition of the objects of the exchanged product data to validate the work package. It represents the reference model for the organisation of the exchanged product data. Its structure is linked to the defined structure of the work packages exchanged between the partners of a cooperative shipbuilding project. On its highest level the exchange package is subdivided into a header with the basic information about the exchange package itself, a documents part to refer to all files connected to the exchange package, a drawings part for the organisation of drawing data, a component package used to generate the "system view" and the work package presenting the "room view". (cf. figure 4).

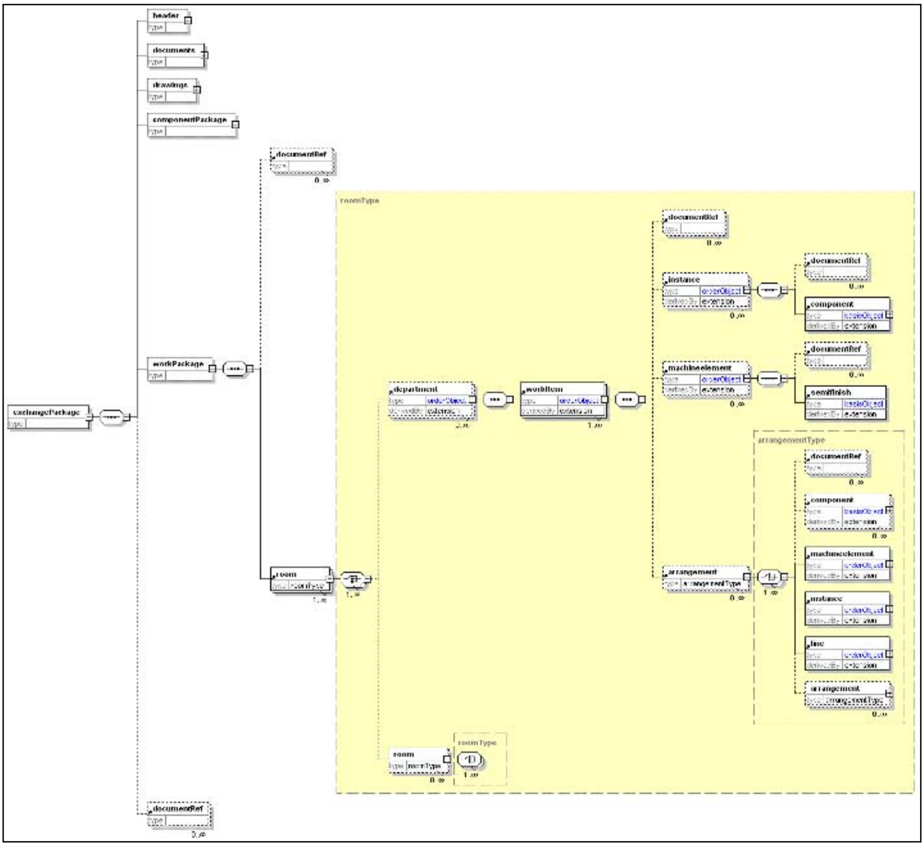

Figure 4. XML scheme of the ship's product data to be exchanged

The XML scheme described above represents a product data model for the exchange of a ship's product data defining an exchange package for design and construction. It supports the exchange of product data independent of a specific shipbuilding project as well as the exchange of project specific data. The data exchange will be realised via a information and communication platform accessible through the internet. This platform comprises three main functions to optimise the communication as well as the exchange of product data between the partners of a shipbuilding project. One function already mentioned before is the screening of the layout structure of the exchange packages via the XML scheme presented above. The

second function is the structured storage of the work packages and their retrieval through the respective partner. Thirdly, there must be a secure correlation of communication via the platform with the exchange package, e.g. if there are modifications or revisions in the work package or in the product data itself [5], or if there is additional need for information. The export and import of the product data via the information and communication platform is explained in figure 5.

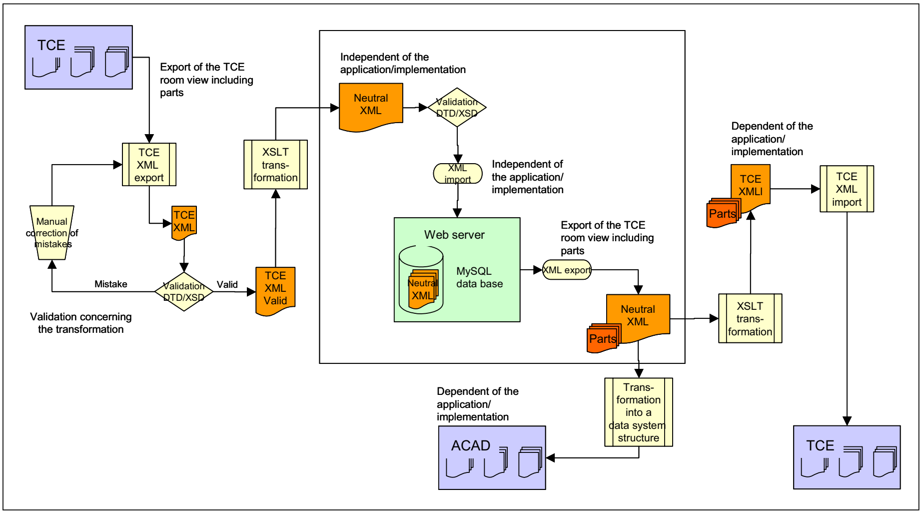

Figure 5. Transfer of product data onto and out of the information and communication platform

6 Conclusion

Especially, the developed product data model helps shipbuilding industry to systematically categorise the complex structures of the product data handled during the life cycle of a ship. The model is of high relevance for realising information technological solutions as well as improving the information and communication structures of cooperative shipbuilding projects. With the suitable communication structure hosted by a communication platform, clearly distinguished construction and design tasks can be transferred to engineering companies or system suppliers fulfilling these tasks. The results of the work of these network partners concerning their work packages have to be re-transferred to the coordinating partner of the shipbuilding project who integrates these results into the overall context. It is imaginable that this integration is automatically done through the communication structure as well. The data exchange will be realised via a neutral XML document with a well defined layout structure. This way the aimed information and communication platform can be utilised by numerous software applications without losing information.

The relevance of the solutions presented in the paper at hand for engineering design is founded by the fact that more and more shipbuilders have to cooperate in developing and producing ships to cope with the strong international competition. To make such a cooperation work there is a need for exchanging data between the partners of a shipbuilding project which efforts usable attributes for identifying the ship’s component parts and a common structure for handling the product data exchanged. Therefore, a practical product

data model is developed. The approach presented in this paper is very much driven by the industrial partners participating in the NET-S project what indicates the high relevance for industrial practice.

Acknowledgement

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Research on Logistics Technology and Analysis on the Beijing Olympic Games Requirements

Lihu LU, Xifu WANG
School of Traffic and Transportation
Beijing Jiaotong University, Beijing, 100044

Abstract. This paper combines with logistics management of Olympic Games and its operational characteristics and the requirement of plan and preparation and organization of BOG (Beijing Olympic Games) in 2008, introduces the meaning and classification, service management and operational mode. With researching on the aim that logistics of BOG should be fulfilled and the effect of modern logistics on the BOG, does helpful exploring on the demand degree of logistics of BOG and correlative technology, and puts forward the basic countermeasures to complete the logistics of Olympic Games.

Keywords: Logistics of Olympic Games; Modern Logistics; Requirement Analysis

1. Introduction

1.1. The Meaning and Classification of Olympic Games Logistics

Succeeding in bidding for the 2008 Olympic Games in Beijing, there was a result at last in the Olympic Games plot of Chinese people coming true, but after regarding as a happiness of the work, it was very arduous Olympic Games preparing and organization work that was put before Beijing Municipal Government and committee of Olympic Games group, the preparing and organizing of the Olympic Games logistics is one of the very important working among them.

According to the definition of logistics in the national standard, combine the research object of this paper, it can define the meaning of the Olympic Games logistics. The Olympic Games logistics is a entity delivery procession from original location to the target location of articles (including the goods and offal) which would be consumed in order to host Olympic Games. According to the actual demand of the Olympic Games, except that combine organically the basic logistics activities such as transportation, storing, loading and unloading, carrying, packing, circulation and processing, distribution, information processing ,etc., also offer various kinds of services of extending according to the need.

Content of the Olympic Games logistics can classify and analyze with different angle of served customer group, relation with Olympic game, region range, time range, service form, and service item content, etc., it classifies as Fig. 1 shows.

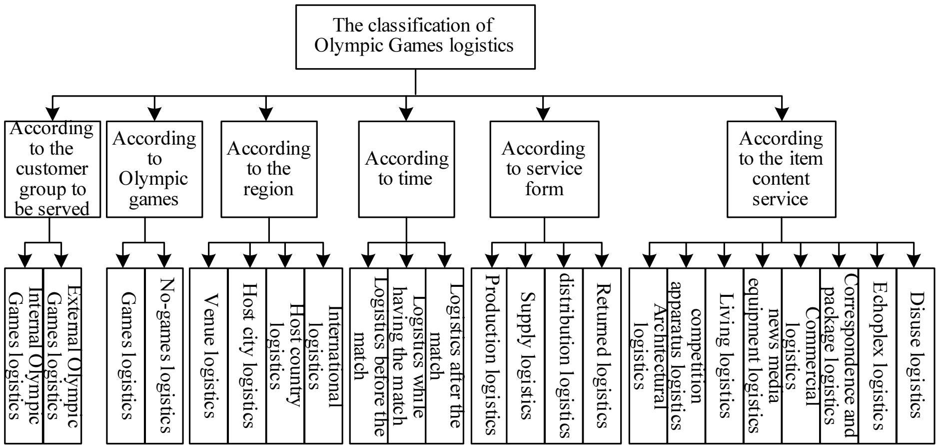

Fig. 1. The classification of Olympic Games logistics

1.2. The Service Management of Olympic Games Logistics

The service management of the Olympic Games logistics divides into three stages: service management of the logistics before the match, service managing of the logistics while managing, service managing of the logistics after the match. The classification of the service item is the building logistics, the competition apparatus logistics, living logistics, news media equipment logistics, commercial logistics of Olympic Games, etc. The basic activity of Olympic Games logistics service includes the activity of transportation, storing, loading and unloading, carrying, packing, circulating and processing, distribution, information processing, etc. In order to prepare this major event of Olympic Games, receival, following, storage, transportation, distribution and installation of a large amount of materials and equip, and returned plan, management and carrying out become the focus that logistics face to and challenge.

1.3. Operation Mode of Olympic Games Logistics

According to basic conditions, such as current situation of logistics service level, demand analysis of the Olympic Games logistics, economic development goal of the host city, etc., layout the Olympic Games logistics. Planning as action outline by programming of Olympic Games logistics, making with outsourcing of most logistics function, coordinating with the logistics supplier of responsible department of Olympic

Games logistics for the operation mode of the market, regarding modern logistics technology as basic service measure, offer high-quality services to Olympic Games logistics.

Organization and operation of the Olympic Games logistics has essential meanings that success to the Olympic Games' running. But because of the characteristic of transient time of the Olympic Games logistics, centralized space, variety of demand main body, uncertainty of requirement, geographical position of host city, rigorous Olympic Games' schedule and security, etc., it makes the organization and management of the Olympic Games logistics very complicated.

Through the analysis of foreign Olympic Games logistics' operation course and mode, It can see that successful Olympic Games logistics operation should include: (1)Set up science, rational Olympic Games logistics programming from strategic aspect; (2)From the tactics aspect, set up the functional department of logistics management of the Olympic Games, which is responsible for the Olympic Games logistics' preparation, establishing service policy and operating criterion of the logistics, negotiating with logistics supplier , and for the organization and management of supervision and coordination of Olympic Games logistics activity; (3) Introduce and popularize advanced modern logistics technology both at home and abroad, including negotiating with the domestic and international logistics suppliers with a advanced technical equipment and management level, high reputation, wrap up outside the activity of the Olympic Games logistics, utilize their advantage of technology and management, form high-efficient, low cost, safe, good Olympic Games logistics service system which takes modern logistics technology as basic means.

2. The Goal and Request of Beijing Olympic Games Logistics

The overall goal of the Olympic Games' logistics decided in "2008 BOG arrangement" is "to ensure a normal and smooth procession of the Olympic Games by relaying on the Beijing logistics industry development strategy which is based on the combination of Digital Olympics, Green Olympics, humane Olympics and our Olympic logistics".

We can detail the goals above by the following 5 concrete items:

(1) To ensure the security of whole operation of the Olympic Games' logistics;
(2) To ensure the controllability for the Olympic logistics operation;
(3) To ensure the high efficiency for logistics management of the Olympic Games;
(4) To ensure the low cost of logistics management for the Olympic Games;
(5) To ensure the flexible and personalized service for the logistics management of the Olympic Games.

In order to realize the items above, management and service of Beijing Olympics should:

(1) Undertake a optimized design for the storage base of Beijing Olympics;
(2) Serve a prompt efficient and excellent service for the logistics procession such as international transportation, passage and check in the customs, air-land sea-land joint transportation , transportation agent and storage during logistics management during and after the match;
(3) Logistics management during and after the games should meet the programmability and sequencing standard and supervise the whole procession. Logistics before the games should be restrained by the last time node. Before the opening ceremony of Beijing Olympics, all articles that will be used in the Olympic Games should be in place. Logistics during the games should secure the whole procession of the food and the game apparatus' logistics. As there should be no damage to the game apparatus during the transportation and storage, otherwise measures are taken in time;
(4) Logistics management during the games should meet the real-time and emergency-countering character. All logistics during should be finished in time fixed. If any time is delayed, emergency of this kind should be deal with efficiently according to schemes prepared ahead of time;
(5) Specific competitive apparatus (such horse-racing) should be stored and delivered according to their specific requirement;
(6) The others.

3. The Effect of Modern Logistics Technology in Beijing Olympic Games Logistics

The application of modern logistics technology plays an important role to guaranteeing that the completion of the Olympic Games logistics work of Beijing, it incorporates as:

(1) Guarantee the management of Olympic Games logistics of Beijing to have controllability

The strict schedule of the Olympic Games logistics, require the management of the Olympic Games logistics to have controllability, guarantee that the goods can reach the match scene within fixed time. The technology of real time following of logistics, the management of the storage and inventory control and optimizing distribution and dispatch etc. in the information technology of modern logistics will offer the technological guarantee and support for controllability of logistics management of the Olympic Games. Such as through the real time following technology of logistics, it can realize the track management of vehicle and goods, improve the transparency of the running of Olympic Games logistics greatly, pinpoint the problems in time, and take measures in time according to the question found, guarantee that the Olympic Games goods reach the match scene within fixed time. Through technology of storage management and inventory control, can offer real-time information of the present stock, the administrator can control and manage the stock through the information that is obtained.

(2) Improve the efficiency of Olympic Games logistics management of Beijing

Olympic Games logistics' space getting centralized and time getting transient prove that flux of Olympic Games logistics is heavy and the velocity is fast, this certainly will require the high-efficiency logistics management system, and the high-efficiency logistics management system needs the support of logistics automatic equipment technology and logistics information technology.

(3) Ensure the security of Olympic Games logistics management of Beijing

The security of the Olympic Games logistics requires that the quantity of material in the logistics of match, such as match apparatus, news apparatus, livelihood material etc., must arrive accurately on schedule, and can't be damaged at all. Require advanced packaging technology, carrying technology, storing technology, real-time logistics following technology and information management technology etc. in logistics to guarantee in this. Because of the uncertainty of the logistics demand during the Olympic Games, collecting, cleaning up and statistical analysis in a large amount logistics information not only has very high commercial value, and can carry on the monitoring and appraisal of the daily operation conditions of logistics system effectively, run the activity to regulate and control of logistics system rationally, once the emergency takes place, it can use the logistics information system to make a response and carry on emergency processing, etc. rapidly.

(4) Make the Olympic Games logistics management have flexibility and individualized

Diversification of the Olympic Games demand, require the flexibility and individualized of logistics management of the Olympic Games. the real time logistics following, storage management and inventory control and distribution optimization technology of modern logistics information technology, and "coordination works of networked Olympic Games logistics information platform" will offer the technological foundation to individualization and management of Olympic Games logistics.

4. The Demand Analyses of Olympic Games for Modern Logistics Technology

Various kinds of modern logistics technology play a different role in realizing the goal of Olympic Games in Beijing.

Use the Analyticl Hierarchy Process (AHP) following to analyse the important degree of meeting the Olympic Games logistics goal in Beijing of various kinds of modern logistics technology. The analyses process of the Analyticl Hierarchy Process (AHP) is omitted.

4.1. Variable Enactment

At first switch the goal layer, request layer and technology layer to appraisal hierarchical structure of AHP of modern logistics technology's relation with the goal and request of BOG logistics, as Fig. 2 shows.

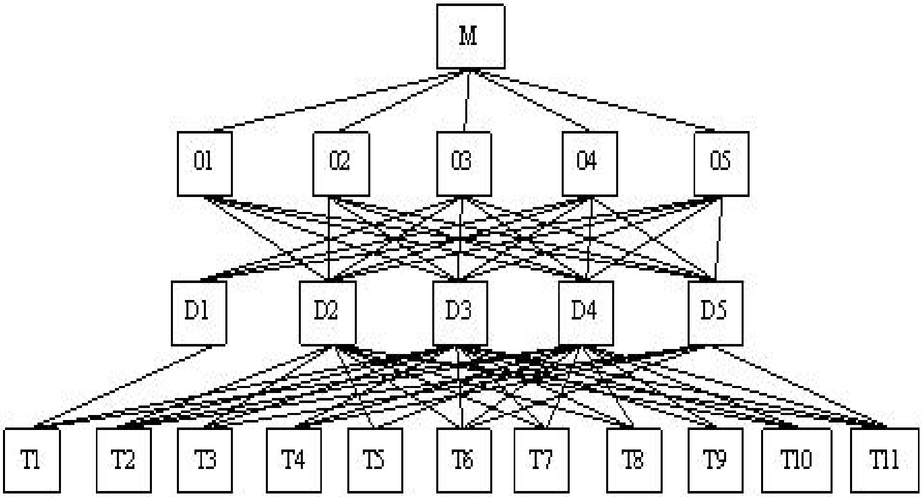

Fig. 2. The analyticl hierarchy in AHP

The meaning of every variable among them is as follows:

Total goal layer:

M: "rely on the logistics industry development strategy of Beijing, make the Olympic Games logistics combine with Digital Olympics, Green Olympics, Peoples Olympics, ensure the going on normally and smoothly of the Olympic Games. "

Branch goal layer:

01: Guarantee the security of whole operation of the Olympic Games logistics;
02: Make the operation of the Olympic Games logistics have controllability;
03: Realize the high efficiency of logistics management of the Olympic Games;
04: Realize the low cost of logistics operation of the Olympic Games;
05: Olympic Games logistics management can offer the flexibility and personalized service.

Request layer:

D1: Optimize and design the storage base of Olympic Games logistics of Beijing;
D2: Offer convenient, high efficiency and high quality service to the logistics course of various kinds of entry and exit goods which serve the Olympic Games;
D3: satisfy the management of "logistics before the match" and "logistics while having the match" which have the request of high security and time controllability;
D4: Meet the real-time request of management of "logistics while having the match";
D5: Meet its special preserving and transportation request to the special match apparatus (such as horse-racing).

Technology layer:

T1: emulation technology of integrated logistics programming;
T2: The real time following technology of logistics;
T3: Storage management and stock control technology;
T4: The optimizing technology of logistics distribution and dispatch;
T5: Integrated software platform technology of the logistics;
T6: Networked Olympic Games logistics coordinated works information platform;
T7: Automatic recognition technology;
T8: The material carrying technology;
T9: Automatic stereoscopic warehouse technology;
T10: Automatic sorting technology;
T11: Special means of transportation.

4.2. Main Analyses Result

The result received according to The Analyticl Hierarchy Process, can draw the following main conclusion:

(1) The importance sequencing of each branch goal to the total goal of Olympic Games logistics work of Beijing as show in table 1.

Table 1. The importance sequencing of each branch goal to the total goal of Olympic Games logistics work of Beijing

serial number	Name of branch goal	Weight of importance
1	O_1: guarantee the security	0.3383
2	O_2: have controllability	0.2950
3	O_3: realize high efficiency	0.2123
4	O_4: realize low cost	0.1095
5	O_5: offer the flexibility and personalized service	0.0485

(2) The importance sequencing of every modern logistics technology to the total goal of Olympic Games logistics work of Beijing as show in table 2.

Table 2. The importance sequencing of every modern logistics technology to the total goal of Olympic Games logistics work of Beijing

Serial number	Name of technology	Weight of importance
1	$T_{6:}$Networked Olympic Games logistics coordinated works information platform	0.1763
2	$T_{2:}$The real time following technology of logistics	0.1527
3	$T_{3:}$ Storage management and stock control technology	0.1406
4	$T_{4:}$The optimizing technology of logistics distribution and dispatch	0.1205
5	$T_{11:}$ Special means of transportation	0.0845
6	$T_{1:}$emulation technology of integrated logistics programming	0.0670
7	T_5:Integrated software platform technology of the logistics	0.0621
8	$T_{7:}$ Automatic recognition technology	0.0608
9	T_8:The material carrying technology	0.0531
10	T_{10}: Automatic sorting technology	0.0502
11	T_9： Automatic stereoscopic warehouse technology	0.0355

Because the logistics system range of Olympic Games is very extensive, and as time goes on, the main content and key link of logistics activity of different stages is different. In order to realize the goal and request of the Olympic Games logistics of Beijing, while making a concrete analysis of the logistics system of the Olympic Games, it should be divided into different link or period to study separately. This paper divide concrete course and technological demand of Olympic Games logistics according to different time of Olympic Games' operation, Olympic Games logistics is divided into three period of time slot of "the logistics before the match", "logistics in having a match", and "logistics after the match" from the angle of time, analyze concretely the demand of BOG logistics for modern logistics technology.

Because the modern logistics technology is different to the contribution rate on realizing the total goal of Olympic Games logistics work of Beijing, the demand degree to them is different. Classify demand degree according to importance 1-5, 5 expresses that the demand degree is the highest, other decreases sequentially. The demand degree to the information technology of the logistics service is different at different stages of the Olympic Games logistics, the concrete demand situation as shown in table 3.

Table 3. The demand degree of Olympic Games logistics for modern logistics technology in different stage

Name of technology	**stage** Logistics before the match	Logistics while having the match	Logistics after the match
emulation technology of integrated logistics programming	5	1	2
The real time following technology of logistics	4	5	4
Storage management and stock control technology	5	5	4
The optimizing technology of logistics distribution and dispatch	3	5	4
Integrated software platform technology of the logistics	5	1	2
Automatic recognition	4	4	4
The material carrying	4	4	4
Automatic stereoscopic warehouse	3	3	3
Automatic sorting	3	4	4
Special means of transportation	5	5	5

5. Research Conclusion

On the premise of meeting logistics service demand of the Olympic Games, offer the chance of participating in Olympic Games logistics practice to logistics enterprises of China as much as possible, especially third-part logistics enterprises, in order to protect its enthusiasm which improves the engineering level, and then promote the development of logistics industry of China.

The concrete method has the following two respects, firstly, adopt the preferential policy, encourage the large-scale third-part logistics enterprises of China such as Cosco, Sinotrans etc. as the cooperative partner (or two packs of units) of traditional contractor of Olympic Games logistics, participate in the logistics jobs among some link of “logistics before the match” and “logistics after the match” (such as transporting, storage, etc.).

Secondly, under the prerequisite of satisfied with request of the Olympic Games logistics service, “logistics while having the match” trust logistics enterprises of China to bear, in order to support and improve the technological level of logistics enterprises especially the third-part logistics enterprises of China.

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Minimum Traversal Circles for Layered Manufacturing Application

Shuo-Yan Chou[a,1], Chang-Chien Chou[a,b], and Yu-Kumg Chen[c]
[a] *Department of Industrial Management, National Taiwan University of Science and Technology*
[b] *Computer Center, Mackay Medicine, Nursing and Management College*
[c] *Department of Electronic Engineering, Huafan University*

Abstract. In order to simplify the problem of layered manufacturing, each geometrical object on the same plane is approximating by its own minimum circumscribed circle. Therefore, the minimum traversal path between circles can be the based model of the minimum traversal path between scanning geometrical objects. By using the concepts of reflection of light in physics and geometrical mathematics, the equation of the minimum traversal path between three circles is derived in this paper. Since there are eight roots in derivation of the equation, some experiments are to carry out the analysis of these roots. With the analysis and the algorithm provided hereby, the roots are reduced so that much applicability of the equation is verified.

Keywords. laminated object manufacturing, stereolithography apparatus, layered manufacturing, path planning, robotic motion planning, geometrical mathematics

1. Introduction

In the field of layered manufacturing (LM) of rapid prototyping, the well-known processes stereolithography apparatus [1] and laminated object manufacturing (LOM) [2] fabricate the prototype of the product object with scanning the cross-sectional contours of the object layer by layer [3]. In order to minimize the total time for completing the fabrication, the minimization of the processing time for each scanning layer is thus essential. For each scanning layer, a laser beam scans along the contours in the layer to solidify the cross-section of the object. The path planning [4] for the scanning each layer is therefore a traversal optimization problem on geometric entities in a two dimensional plane [5, 6]. Figure 1 illustrates the concepts of a LM example in rapid prototyping.

Since the shapes of objects on each scanning plane are different, it is very difficult to figure out the minimum traversal path among these objects. By using some smallest circumscribed circles to approximate these objects, the problem can be simplified as finding the minimum traversal path between circles. Therefore, finding the minimum traversal path between circles can be used in the path planning of LM. Finding the minimum traversal path between three circles is the fundamental case of finding the minimum traversal path between circles. The problem can be defined as follows. Given three disjoint circles, find the path that traverses all three circles in sequence for which the sum of the circumferences of the three circles and the two connecting links is a minimum.

[1] Corresponding Author: 43 Keelung Road, Section 4, Taipei, Taiwan; sychou@im.ntust.edu.tw.

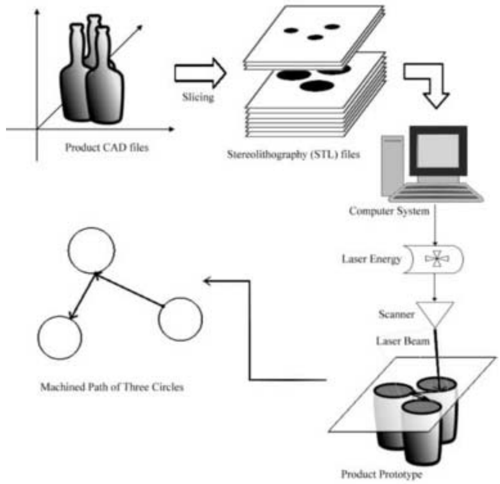


Figure 1. The processes of the layered manufacturing in rapid prototyping.

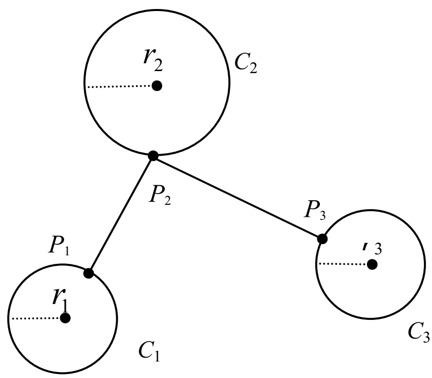


Figure 2. Traversal path among three circles.

Figure 2 shows three circles C_1, C_2, and C_3 with their centers O_1, O_2, O_3, and radii r_1, r_2, r_3, respectively. The starting point is at point P_1. Traverse the circumference of C_1 and then return back to the point P_1. Traverse the link $\overline{P_1P_2}$ and then arrive the point P_2 on C_2. Traverse the circumference of C_2 and then return back to the point P_2. Then traverse across the link $\overline{P_2P_3}$ to reach the point P_3 on C_3. Finally, traverse the circumference of C_3 and come back to the point P_3 to finish up this traverse. To get the minimum length of this traversal path is the goal of the proposed paper.

In this paper, the problem of the minimum traversal path of three circles can be further degenerated to solve the minimum traversal path of two points and one circle. With applying the light reflection (or refraction) phenomenon and geometrical mathematics, the minimum traversal function can be derived in this paper. Since there are many roots derived, a coordinate transferring algorithm accompanies some

experiments are designed to simulate and analyze these roots. Some geometrical properties of these roots are also found and discussed in this paper that lead to reducing the complexity of the roots' function.

2. Problem Transformation

In this paper, we use E_y^x to represent the problem of finding the minimum traversal path for x distinct points and y disjoint circles in a two dimensional plane. The goal of the proposed paper is to find the minimum traversal function among three disjoint circles C_1, C_2, and C_3. This problem is thus can be represented as E_3^0, i.e., finding the minimum traversal path for 0 distinct points and 3 disjoint circles in a two dimensional plane. The path of E_3^0 is an open route, i.e., the starting point of the traverse needs not coincide with the end point of the traverse.

Under the E_3^0 condition, we denote the length of the minimum traversal path by L_3^0. The function *dist*(*UV*) represents distance between point U and point V. And the function *cirf*(*C*) represents the length of circumferences of the circle C. Thus, we can write

$$L_3^0 = \min\{dist(P_1 P_2) + dist(P_2 P_3) + cirf(C_1) + cirf(C_2) + cirf(C_3)\}. \tag{1}$$

Since the radii of the given three circles are constants, this property is provided by the following simple lemma.

Lemma 1 Given three disjoint circles C_1, C_2, and C_3 in the two dimensional plane. The problem E_3^0 of these circles can be reduced to the problem E_1^2 for one circle C_2 with two points O_1 and O_3 by adding a constant value.

The minimum traversal length L_1^2 of E_1^2 can be simplified as

$$L_1^2 = \min\{dist(O_1 P_2) + dist(O_3 P_2)\} + cirf(C_2).$$

With replacing the C_2 by C, P_2 by P, O_1 by A, O_3 by B and removing the constant term $cirf(C_2)$, the problem can be simplified as finding the minimum traversal length L of the sum of the two interconnecting line segments $\overline{AP}$ and $\overline{PB}$, so that

$$L = \min\{dist(AP) + dist(P B)\}, \quad P \in C. \tag{2}$$

In order to simplify the derivation of equation, we assume that the center of circle C coincides with the origin. Figure 3 shows the relationship between points A, B, P, and circle C for an E_1^2 problem. Let (x_A, y_A), (x_B, y_B), and (x_P, y_P) be the coordinates of points A, B, and P, respectively. Let $\ell(x_P, y_P)$ be the distance function of the real variables x_P and y_P. It is defined by the equation

$$\ell(x_P, y_P) = \sqrt{(x_A - x_P)^2 + (y_A - y_P)^2} + \sqrt{(x_B - x_P)^2 + (y_B - y_P)^2}\ . \tag{3}$$

If we introduce the polar coordinates $x_P = r\ \cos\theta$ and $y_P = r\ \sin\theta$, then $\ell(x_P, y_P)$ becomes $\ell(r,\theta)$. Since the radius r in the proposed paper is a constant, the function $\ell(r,\theta)$ can then be denoted as $\ell(\theta)$. Direct substitution in Eq. (3) yields

$$\ell(\theta) = \sqrt{(x_A - r\cos\theta)^2 + (y_A - r\sin\theta)^2} + \sqrt{(x_B - r\cos\theta)^2 + (y_B - r\sin\theta)^2} \tag{4}$$

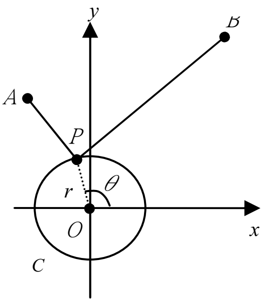


Figure 3. An example of E_1^2 problem.

3. Derivation of Equations

There are many approaches to find the extreme values. The most well-known approach is using the first-order derivative for function $\ell(\theta)$ with respect to θ to be equal to zero. With applying the linear programming or numerical analysis methods, we also can find the extreme value or approximate extreme values. However, the E_1^2 problem cannot be solved by using all of these methods. In this paper, we propose a new method which combines the law of light reflection in physic and geometrical mathematics to find the minimum values of P resulted in the minimum traversal path of the E_1^2 problem. Let the index of refraction of the medium with the incident ray be n_1 and that of the medium with the refracted ray be n_2. Figure 4(a) illustrates the refraction of light between these two different mediums. The included angles of incident and refracted lines to the normal line N are θ_1 and θ_2, respectively. Then $n_1 \sin\theta_1 = n_2 \sin\theta_2$. This result, found by Willebrord Snell, is known as Snell's law. If the both side refractive mediums are the same, i.e., $n_1 = n_2$, the incident angle θ_1 is then equal to the refractive angle θ_2.

Reflection is a special case of refraction. Figure 4(b) shows an example of light reflection. The direction of dotted line N in Figure 4(b) is also perpendicular to the surface of the plane M. The light emits from the direction of $\overrightarrow{AP}$ to the plane M, and then makes the reflection with the direction of $\overrightarrow{PB}$. Let θ_1 denote the incident angle and θ_2 denote the reflection angle. With respect to the Snell's Law, we also have the equation $n_1 \sin\theta_1 = n_2 \sin\theta_2$ for the reflection. Since the light emission and reflection are at the same side, the mediums of both light directions are the same, i.e., $n_1 = n_2$. We get $\theta_1 = \theta_2$.

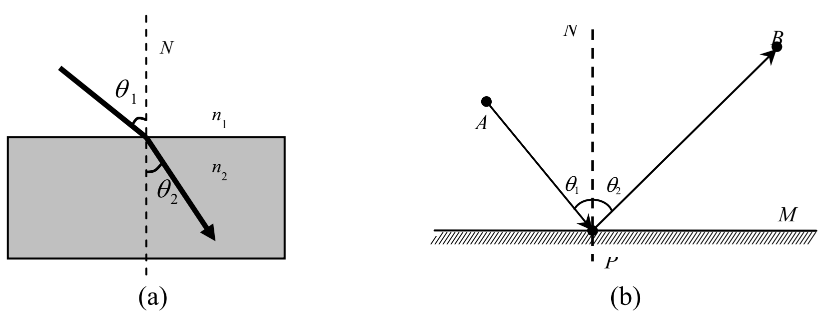


Figure 4. (a) The refraction of light between different mediums, and (b) Example of the light reflection.

Based on the theory of Fermat's principle, light traverses along the least time path. The light quickest traversal path from point A, via plane M, and to point B is the set of line segments $\overline{AP}$ and $\overline{PB}$ with $\theta_1 = \theta_2$. Since the mediums of both sides the same, the speed of light is constant and the light quickest traversal path is equal to the minimum traversal path. We then have

Lemma 2 With the incident angle θ_1 equal to the reflection angle θ_2, the length of traversal path along the line segments $\overline{AP}$ and $\overline{PB}$ is the shortest path.

By applying the principle of light reflection to the E_1^2 problem, M is the tangent line to circle C at point P. Figure 5. shows the relationship of the light reflection and the E_1^2 problem. In order to simplify derivation of solutions, let the center of circle C be coincide with the origin. The traversal path can be found by any given point P on circle C. Hence, the minimum traversal path can be derived from these traversal paths. The coordinates of point A^* is (x_{A^*}, y_{A^*}).

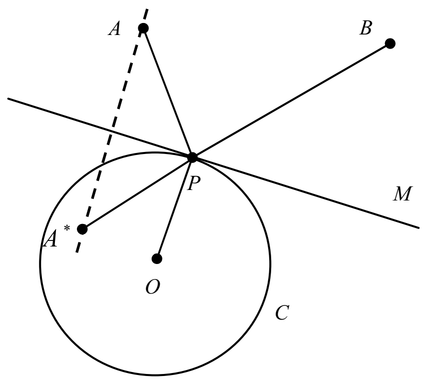


Figure 5. The relationship of the light reflection and the E_1^2 problem.

Since P is a tangent point for line M to circle C, the line segment $\overline{OP}$ is perpendicular to M. Since the point A^* is the mirrored point of A against M, the line $\overline{AA^*}$ is perpendicular to M, too. The slope of line $\overline{AA^*}$ is equal to the slope of line segment $\overline{OP}$, that is,

$$\frac{y_A - y_{A'}}{x_A - x_{A'}} = \frac{y_P}{x_P}. \tag{5}$$

Both lengths of the line segments $\overline{AP}$ and $\overline{A^*P}$ are equal, we have

$$\sqrt{(x_P - x_A)^2 + (y_P - y_A)^2} = \sqrt{(x_P - x_{A'})^2 + (y_P - y_{A'})^2}. \tag{6}$$

By solving the simultaneous Eqs. (5) and (6), and introducing the polar coordinates

$$\theta = \begin{cases} \theta_1 = -\cos^{-1}(\frac{1}{4}k - n - \frac{1}{2}\sqrt{q-p}) \\ \theta_2 = \cos^{-1}(\frac{1}{4}k - n - \frac{1}{2}\sqrt{q-p}) \\ \theta_3 = -\cos^{-1}(\frac{1}{4}k - n + \frac{1}{2}\sqrt{q-p}) \\ \theta_4 = \cos^{-1}(\frac{1}{4}k - n + \frac{1}{2}\sqrt{q-p}). \end{cases} \qquad \theta = \begin{cases} \theta_5 = -\cos^{-1}(\frac{1}{4}k + n - \frac{1}{2}\sqrt{q+p}) \\ \theta_6 = \cos^{-1}(\frac{1}{4}k + n - \frac{1}{2}\sqrt{q+p}) \\ \theta_7 = -\cos^{-1}(\frac{1}{4}k + n + \frac{1}{2}\sqrt{q+p}) \\ \theta_8 = \cos^{-1}(\frac{1}{4}k + n + \frac{1}{2}\sqrt{q+p}) \end{cases} \tag{7}$$

where k, n, p, q are as follows:

$$k = \frac{r(ax_B + bx_A)}{ab}, \quad n = \frac{1}{2}\sqrt{\frac{l}{2} + \frac{1}{j}(\frac{g}{h} + h)}, \; p = \frac{m}{8a^3b^3n}, \quad q = l - \frac{1}{j}(\frac{g}{h} + h),$$

where a, b, c, d, e, f, g, h, j, l, m are

$$\begin{aligned}
&a = x_A^2 + y_A^2 \\
&b = x_B^2 + y_B^2 \\
&c = 2r^2 x_A x_B + r^2 y_A^2 + x_B^2(r^2 - 4y_A^2) + 2r^2 y_A y_B + r^2 y_B^2 - 4y_A^2 y_B^2 + x_A^2(r^2 - 4b) \\
&d = 2x_A^2 x_B + x_B y_A (y_A - y_B) + x_A(2x_B^2 - y_B(y_A - y_B)) \\
&e = x_B^2(-r^2 + y_A^2) - 2x_A x_B (r^2 - y_A y_B) + x_A^2(-r^2 + y_B^2) \\
&f = 36r^2(6e(ax_B + bx_A)^2 + cd(ax_B + bx_A) + 6abd^2) \\
&g = c^2 + 48abe + 24r^2 d(ax_B + bx_A) \\
&h = \frac{1}{\sqrt[3]{2}}\sqrt[3]{2c^3 - 288abce + 2f + \sqrt{-4g^3 + 4(c^3 - 144abce + f)^2}} \\
&j = 12ab \\
&l = -\frac{c}{3ab} + \frac{r^2(ax_B + bx_A)^2}{2a^2b^2} \\
&m = r(r^2(ax_B + bx_A)^3 - abc(ax_B + bx_A) - 4a^2b^2d).
\end{aligned}$$

From Eq. (7), the resolved eight angles can derive the corresponding locations of eight points P_1, P_2, P_3, P_4, P_5, P_6, P_7, and P_8 on the circle C with their coordinates (x_{P_1}, y_{P_1}), (x_{P_2}, y_{P_2}), (x_{P_3}, y_{P_3}), (x_{P_4}, y_{P_4}), (x_{P_5}, y_{P_5}), (x_{P_6}, y_{P_6}), (x_{P_7}, y_{P_7}), and (x_{P_8}, y_{P_8}), respectively. Substituting the eight solutions of angle θ into Eq. (4) yields the eight lengths. With finding the shortest length of these eight lengths, we can get the solution of this problem. From Eq. (2), the minimum traversal length L can be rewritten as

$$L = \min\{\ell(\theta_1), \ell(\theta_2), \ell(\theta_3), \ell(\theta_4), \ell(\theta_5), \ell(\theta_6), \ell(\theta_7), \ell(\theta_8)\}. \tag{8}$$

4. Analyses and Simplifications of Equations

In order to simplify the E_1^2 problem, the problem can be restricted in the first quadrant or the first and the second quadrants with two-dimensional rotation of the E_1^2 problem. In order to analyze the relationships of the eight roots and then simplify the solution, an eight-root-curve diagram is developed in this paper. The eight-root curves diagram constructing assumes that the initial locations of point A lie on the negative x axis and point B lie on the positive x axis. Let ϕ be the angle of the vector $\overrightarrow{OB}$ with respect to the x axis. With fixing the point A and turning the point B around the origin, we can obtain the eight-root curves diagram. The eight-root-curve diagram shows the traversal length $\ell(\theta,\phi)$ as a function of ϕ within the interval [0, 2π] for the eight roots of θ, that is,

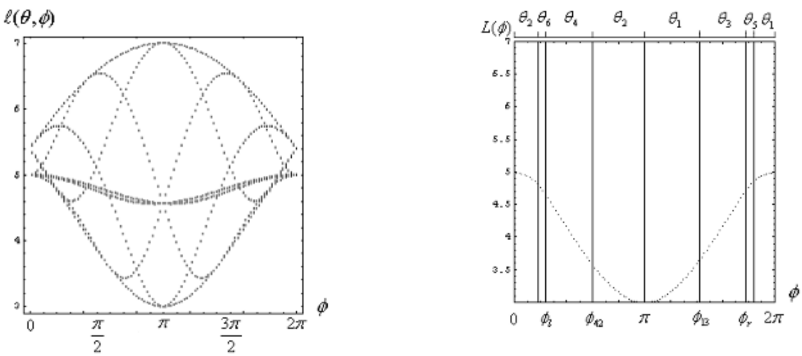
$$\ell(\theta,\phi) = \sqrt{(x_A - r\cos\theta)^2 + (r\sin\phi - r\sin\theta)^2} + \sqrt{(x_B - r\cos\theta)^2 + (r\cos\phi - r\sin\theta)^2}.$$

For each angle α of the point B turned, we can derive eight solutions of point P on the circle C and eight traversal lengths $\ell(\theta_1,\phi)$, $\ell(\theta_2,\phi)$, $\ell(\theta_3,\phi)$, $\ell(\theta_4,\phi)$, $\ell(\theta_5,\phi)$, $\ell(\theta_6,\phi)$, $\ell(\theta_7,\phi)$, and $\ell(\theta_8,\phi)$. With connecting the solutions of different locations of point B, we can derive a curve of traversal length $\ell(\theta,\phi)$ for each solution. After combining the eight curves, the eight-root curves diagram is completed, as shown in Figure 6(a).

Because of equations $\ell(\theta_1,\phi) = \ell(2\pi-\theta_2,\phi)$, $\ell(\theta_3,\phi) = \ell(2\pi-\theta_4,\phi)$, $\ell(\theta_5,\phi) = \ell(2\pi-\theta_6,\phi)$, and $\ell(\theta_7,\phi) = \ell(2\pi-\theta_8,\phi)$, the symmetry property exists between the curves of pairs $\ell(\theta_1,\phi)$ and $\ell(\theta_2,\phi)$, $\ell(\theta_3,\phi)$ and $\ell(\theta_4,\phi)$, $\ell(\theta_5,\phi)$ and $\ell(\theta_6,\phi)$, $\ell(\theta_7,\phi)$ and $\ell(\theta_8,\phi)$. Figure 6(a) demonstrates that the magnitudes of the values $\ell(\theta,\phi)$ from π to 2π are reflections of the values in the half period to the left of the origin. If the initial location of point A does not lie on the negative x axis, we can get its eight-root-curve diagram, too.

By using Eq. (8) for the example in Figure 6(a), we can derive the curve of the minimum traversal length L with respect to angle ϕ, as shown in Figure 6(b). This curve can also be derived from the bottom envelop of the eight-root-curve diagram in Figure 6(a). It is a composite curve assembled by the traversal length $\ell(\theta,\phi)$ with the order sequence of $\ell(\theta_2,\phi)$, $\ell(\theta_6,\phi)$, $\ell(\theta_4,\phi)$, $\ell(\theta_2,\phi)$, $\ell(\theta_1,\phi)$, $\ell(\theta_3,\phi)$, $\ell(\theta_5,\phi)$, and $\ell(\theta_1,\phi)$ for ϕ from 0 to 2π. In this result, the curves of the $\ell(\theta_7,\phi)$ and $\ell(\theta_8,\phi)$ does not appear in the minimum traversal length curve in Figure 6(b). With removing the solutions of angles θ_7 and θ_8 in Eq. (8), we thus obtain

$$L = \min\{\ell(\theta_1),\ell(\theta_2),\ell(\theta_3),\ell(\theta_4),\ell(\theta_5),\ell(\theta_6)\}\cdot \tag{9}$$



(a) (b)

Figure 6. (a) The eight-root-curve diagram and (b) the minimum traversal length curve.

The angles ϕ_l and ϕ_r are two angles where the line $\overline{AB}$ makes the tangent of the circle C. When the angle ϕ lies on the intervals [0, ϕ_l] and [ϕ_r, 2π], there exists at least one line segment $\overline{AP}$ or $\overline{PB}$ that makes the secant of the circle C. Under this condition, we can get the line segment $\overline{AB}$ as the solution of this E_1^2 problem immediately. Therefore, it need not be solved when ϕ lies on the intervals [0, ϕ_l] and [ϕ_r, 2π]. There are four solutions of angles θ_1, θ_2, θ_5, and θ_6 used in these intervals. Since the angles θ_5 and θ_6 are not used in the other intervals, we can erase them from the set of the solution. From equation (26), the expression may be written as

$$L=\min\{\ell(\varpi_1),\ell(\varpi_2),\ell(\varpi_3),\ell(\varpi_4)\}. \tag{10}$$

From Figure 6(b), reflection occur about the line φ = π. Therefore, Eq. (10) becomes

$$L=\min\{\ell(\varpi_2),\ell(\varpi_4)\}. \tag{11}$$

Let φ_{42} and φ_{13} be the angles of $\ell(\varpi_4,\varphi)=\ell(\varpi_2,\varphi)$ and $\ell(\varpi_1,\varphi)=\ell(\varpi_3,\varphi)$, respectively. The eight solutions of angle υ can be reduced to a two-root function, that is,

$$\theta=\begin{cases}\theta_2=\cos^{-1}(\frac{1}{4}k\text{ - }n-\frac{1}{2}\sqrt{q-p}),\text{if }\phi_{42}\le\phi\le\pi \\ \theta_4=\cos^{-1}(\frac{1}{4}k\text{ - }n+\frac{1}{2}\sqrt{q-p}),\text{if }\phi_{\ell}\le\phi<\phi_{42}\end{cases}. \tag{12}$$

5. Conclusions

In this paper, the minimum traversal path of three circles is defined as a E_3^0 problem, and is transformed into the E_1^2 problem. With applying the law of light reflection and geometrical mathematics, the eight roots of solution function of the minimum traversal path of three circles is derived. We develop a eight-root-curve diagram for simplification of the equation. By experimental analysis and classification, we get a two-root solution function for this problem. Using the proposed algorithm of the problem rotation, the problem can be transformed to the problem in first quadrant or the first and the second quadrants. This solution can be effectively used in solving a variety of engineering applications, such as layered manufacturing, robotic motion planning, and path planning. In more than three circles, the problem of finding the minimum traversal path is still essentially open.

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Study on Rough set-based Clustering Result Presentation Method for High Dimensional Data Space

CHEN Jianbin[1], Gao Yinmin
Business College of Beijing Union University, Beijing, China

ABSTRACT Since the internal structure of data set is unknown before clustering, the clusters should be presented properly, so that user can get the result completely and accomplish the task of knowledge discovering. The presentation and explanation of the clustering result play an important role in the clustering process. Based on the study of rough set, the rough set theory on attribute space is imported and a new clustering result presentation method is advanced, with the different property consideration of the object space and attribute space of high dimensional data set. This method can provide relatively synthesis information of clustering result from object space and attribute space, reflect the clustering knowledge with rules, enable users to capture more useful pattern and to hold the internal structure of data sets.

Keywords. Clustering Result Presentation, High-dimensional data space, Rough set

1. Related Work

It is very important to study the presentation method of clustering result. Since the division of data set can not be known before clustering, the clustering result should be presented properly to be understood. In the case of low dimension, visualization can be used to interpret the data structure. But in the case of high dimension, it is not so easy to present the clustering result. There are many technologies which have been proposed with many clustering algorithms, such as visualization, minimal expression and representation objects methods.

OPTICS[1] is a typical clustering algorithm which adopted the visualization method to presenting the clustering results. At the same time, CLIQUE[2] adopted the minimal expression method. It is a clustering algorithm which is designed for high-dimensional data space, with the concept of subspace to clustering. To present the clustering result, CLIQUE uses a minimal expression to be understood more easily. Wu sen[3] proposed a new method for cluster representation which imports the concept of pattial order relation and finite border of set theory, and [2] define the cluster representation method based on the power set of attribute set for the CABOSFV clustering algorithm.

There are many algorithms which apply representation objects methods. In *k-means*, the cluster center was looked as the represent object of cluster. And in PAM, CLARA

[1] Chen Jianbin, A3,Yanjingdongli,Chaoyang, Beijing,100025,P.R.CHINA Phone: 086-10-65940656 FAX: 086-10-65940655 E-mail: jianbin.chen@bcbuu.edu.cn

and CLARANS, it is the medoid object as the represent object. These medoids are k objects nearest to the k cluster centers individually, and in this case, the quality of clustering is up to the most optimization. CURE adopts a middle ground between centroid-based and representative-object-based approaches. Instead of using a single centroid of object to represent a cluster, a fixed number of representative points in space are chosen. The representative points of a cluster are generated by first selecting well-scattered objects for the cluster and then "shrinking" or moving them toward the cluster center by a specified fraction, or *shrinking factor*.

2. Data Visualization Technique

Among those methods of clustering result presentation, the data visualization technique would be the most frequency to be used, besides the representative objects methods. The visualization technique used by OPTICS is a typical method of clustering structure presentation. It can be used as an important tool to discover data distribution, and find varies clusters with different scale, density and shape. But it is also limited in those problems, such as the selection of parameter, the index technique and the dynamic updating technique.

Data visualization has a tighten relation with visual data mining. Data visualization is the graphical presentation of information, with the goal of providing the viewer with a qualitative understanding of the information contents. The data visualization can be used to construct visual data mining system, such as visual clustering[4]. There are several traditional visual techniques on multidimensional data sets, such as glyph techniques[5][6], parallel coordinates[7], scatterpolt matrices[8] and pixel-level visualization[9]. But it is so difficult to deal with high dimensional data set for these techniques. Dimension reduction methods, such as Principal Component Analysis[10], Multidimensional Scaling and Kononen's Self Organizing Maps, have been designed to deal with high dimensional data sets specially. The shortcoming for them is that the educed subspace is too less intuitional means to be interpreted and understood. For very highly dimensional data sets, the dimension reduction techniques are so inefficient that has not been useful.

3. Knowledge Presentation Based on Rough set Theory

Summarizing all these methods of presentation of clustering results, they all have limitations more or less, whether the visualization, minimal expression or the representation objects methods. It is difficult for the visualization of high-dimensional data set because of the number of objects and dimensions are so large. Even the high-dimension data set can be transferred lower, the presentation of clustering result also means the distribution of data objects only on object space, no information on attribute space.

One of the aims of clustering knowledge presentation is to reflect the currently information of the data objects distribution, another is to analysis and forecast the future information by means the data distribution and clustering rules, that is to gain a kind of knowledge. A concept of knowledge consists of intension and extension[11]. The intension of concept can be explained by object attributes, and the extension of concept can be explained by object itself. There are so many data sets besides the

clusters made by clustering. For example, there are 2^n-1 data subsets which are not empty, but there are *k* clusters only. If the *k* clusters can be regarded as meta knowledge, then how to express those subsets with these meta knowledge would be a problem. On the other side, the clustering knowledge can be understood just because it can be described by attribute values. But there are so many combination methods for the attributes value, and the clustering knowledge are so little, that it also can be a complex problem to describe and understand those attribute value sets with these known clustering knowledge. It is called *knowledge merge* in knowledge discovering of information system domain.

So, a perfectly clustering knowledge presentation method should provide three kinds of information, firstly the distribution of objects, secondly the relationship of the objects distribution and the attributes set, and thirdly, the rules how to assign new objects to clusters. This paper constructed a new method of clustering knowledge presentation based on rough set theory, imported the rough set theory on attributes space. It can express the clustering rules on object space and attribute space at the same time.

4. Rough set Theory Based on Attribute Space

In Pawlak's rough set theory, object space can be partitioned based on equivalence relation, and the subsets of object space can be expressed by these equivalence relation. The equivalence class can be expressed by attributes set, so it can be understood. But those subsets besides of the equivalence class can not be expressed by attributes set, so they can't be understood. Then it is essential to build rough set theory based on attributes space[11].

5. Projected clustering algorithm

5.1. Definition

In Clustering Knowledge Discovery, information system can be regarded as a table, that is object-attribute table. In the information system $I = (U, A, V, f)$, in which U is a data set with N objects in it. That is

$U = \{X_1, X_2, ..., X_N\}$;

And A is an attributes set:

$A = \{a_1, a_2, ..., a_m\}$.

F is a relation set of U and A. V is the value range of attributes. The value range $V_j (j<=m)$ can be continuous, discrete or categorical. But if it is needed, the value space should be normalized and discretization to get limited number values for V_j , and

$$V = \bigcup_{j=1}^{m} V_j$$

Then $f_j : U \to V (j \le m)$.

If the character for an object belonging to a cluster can be regarded as an attribute of object, the attribute G can add to attribute set A, and there are two parts in the set, the original attributes which called condition attribute set E, and the single attribute which called decision attribute G. that is

$$A = \{e_1, e_2, ..., e_D, G\}.$$

5.2. Clustering Knowledge Representation on Object Space

Clustering can get data partitions with rules such as object similarity. If the similarity relation is reflexivity, symmetry and transitivity, the similarity based on combination of attributes can be regarded as an equivalent relation, and the clustering results an equivalence-class, $U/R=\{C_1,C_2,...,C_K\}$. If there is a unique name for them, they become various concepts which can be presented by attribute set, and can be understood. Given an integer number for each cluster, then the value range of attribute G is $V_G=\{1,2,...,K\}$. The parallelism relation $\{X_i,G_V\}$,which means the object and its cluster belonging to can be called the clustering knowledge presentation on object space.

We not only consider which cluster an data object belongs to, but also the attribute rules of these clusters. The latter is more important because it can enable classify new data objects.

5.3. Clustering Knowledge Representation on Attribute Space

Assumed that the number of value of each attribute is limited, if an object get value v_j in the attribute e_i, then (e_i,v_j) is a meta formula. A data object can be described by a set of meta formulas. A cluster is an union of meta formulas of the data object which belongs to. Given

$$\varphi_{ij} = (e_j, v_{ij} : v_{ij} \in V_j),\ (i = 1,2,...,N; j = 1,2,...,D)\ ;$$

$$X_i = \left\{ \underset{e_j \in E}{\wedge} (e_j, v_{ij}) \right\},\ (i = 1,2,...,N; j = 1,2,...,D),$$

$$C_k = \{\vee X_i : i = 1,2,...,n_k\},$$

$$C = \{\vee C_k : k = 1,2,...,K\}.$$

In the extraction operation $\vee$, the frequency can be computed for each meta formula,

$$\pi(\varphi_{ij}) = \frac{|\varphi_{ij}|}{|C_k|},$$

which $|\varphi|$ means the number of φ in C_k, and $|C_k|$ means the number of whole formulas in C_k. Borrowed the concept of Upper and Lower Approximation of ψ in rough set, the clustering knowledge presentation of the data set on attribute space can be defined as follows:

For $C_k \in C$, the *Lower Approximation* of C_k on attribute space is

$$\underline{B}(C_k) = \vee\{\varphi_{ij} \in C_k : \pi(\varphi_{ij}) = 1\}$$

And the *Upper Approximation* is

$$\overline{B}(C_k) = \wedge\{\varphi_{ij} \in C_k : 0 < \pi(\varphi_{ij}) \leq 1\}$$

The *Feature Precision* of C_k on attribute space can be

$$\alpha(C_k) = \frac{|\overline{B}(C_k)|}{|\underline{B}(C_k)|}$$

Imported the decision attribute *G,* there are K meta formulas, $\sigma(G) = \{\vee(G, V_{Gi}) : V_G = (1,2,...,K)\}$. If $\sigma(E)$ means the whole formula based on original attribute space $E=\{e_1,e_2,...,e_D\}$, for $\varphi \in \sigma(E), \psi \in \sigma(G)$, the $\varphi \rightarrow \psi$ can be a rule. With the probability distribution *P* on data set *U*, the frequency can be computed for each rule, $\pi(\psi / \varphi) = P(\|\psi\| / \|\varphi\|)$.

For each $\psi \in \sigma(G)$, if $A(\psi)$ is the condition set, the *decision rule* can be expressed as

$\varphi \in \underline{B}(C_k) \rightarrow \psi_k$.

About the clustering knowledge presentation on attribute space can be explained as: If all the data objects get same value in an attribute, then the meta knowledge in this attribute is unique, and it is an assured attribute of this cluster. The assured knowledge constructed by assured attribute is the *Lowed Approximation* set for this cluster on attribute space. If all the data objects get various values in an attribute, the attribute contains more than one meta knowledge which has various weightings. These meta knowledge and attributes constructed by them is the *Supper Approximation* set. The *Feature Precision* reflects the total similarity of data objects. Less the value of a cluster *Feature Precision*, higher the total similarity for all data objects in this cluster, and vice versa.

5.4. The Clustering Information Vector of data set and its operations

For the clustering result of information system $I = (U, A, V, f)$, a Clustering Information Vector can be defined.

Definition 1(**Clustering Information Vector, CIV**) For information system $I=(U,A,V,f)$, in which $X\subseteq U$. The Vector

$$CFV(X)=(|X|,S(X),\underline{B}(X),\overline{B}(X),\alpha(X))$$

can be called *Clustering Information Vector(CIV)* of data set *X*, in which

$|X|$ is the number of data objects in it;

$S(X)$ is the ID set of the objects in *X*, denote which object belongs to it;

And $\underline{B}(X),\overline{B}(X),\alpha(X)$ are *Lower Approximation, Supper Approximation* and *Feature Precision* of data set *X* on attribute space.

After the *CIV* of data set has been defined, the *Total Clustering Vector* can be defined as

$$U_{CFV}=(CFV(C_1),CFV(C_2),...,CFV(C_K)),$$

In which $CFV(C_i)=(|C_i|,S(C_i),\underline{B}(C_i),\overline{B}(C_i),\alpha(C_i)),i=1,2,...,K$.

The *CIV* of data set enables us to resumptively express the clustering characters of a data set as a whole. With the vector, we can know which data object belongs to this cluster, how many of them on object space, also we can know the attribute distribution on all data object, and their coherence which reflect the convergence of data set on the attribute. The coherence of data set in whole can also be computed on attribute space.

The *CIV* of data set combined the clustering knowledge representation on object space and attribute space, expressed the clustering result from intension and extension perfectly. The clustering knowledge representation based on rough set theory is more meaningful for high dimensional data. It is easier to express the relation of data cluster and attribute for low dimensional data because the simple and less attribute set. But it is more difficult for high dimensional data set to be expressed by visualization method, or others which are effective in low dimension. The method proposed in this paper based on rough set theory can provide enough information of clusters and correlative attributes, divide attribute set into multilayer, give the inherence relation of clustering knowledge.

With the additivity of vector, we can define the increment clustering.

Definition 2(**the Addition of CIV**) For information system $I=(U,A,V,f),X,Y\subseteq U$, the corresponding *CIVs* are

$$CFV(X)=(|X|,S(X),\underline{B}(X),\overline{B}(X),\alpha(X)),$$

$$CFV(Y)=(|Y|,S(Y),\underline{B}(Y),\overline{B}(Y),\alpha(Y)).$$

The *Addition of CIV(ACIV)* defined as

$$CFV(X\cup Y)=(|X+Y|,S(X\cup Y),\underline{B}(X\cup Y),\overline{B}(X\cup Y),\alpha(X\cup Y)).$$

Based on the definition of ACIV, the CIV of new data set merged by two old set can be computed easily. This can be applied in hierarchical clustering or incremental clustering to merge little clusters or add more new data object. The quality of clustering

can be reflected by the *Feature Precision* of data set on attribute space. So we can add or delete data object, or merge little clusters by computing the **Feature Precision.**

6. Conclusion

In this paper, we studied the problem of clustering result presentation. We proposed a new clustering knowledge representation method based on rough set theory. The method of clustering knowledge representation on attribute space has been discussed, and the concepts of *Low Approximation, Upper Approximation* and *Feature Precision* have been defined for data set on attribute space. The CIV proposed in this paper combined the method of information representation on object space and attribute space, expressed clustering knowledge perfectly in intension and extension of concept. This method can provide plenty of information, simple, intuitive and suitable for high dimensional data set, it is a good method for clustering information representation and data reduction.

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CE Perspectives

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Virtual Reality systems and CE: how to evaluate the benefits

Maura MENGONI [1], Michele GERMANI
Polytechnic University of Marche, Department of Mechanics, Ancona, ITALY
m.mengoni@univpm.it, m.germani@univpm.it

Abstract. Virtual Reality systems and Virtual Environments represent innovative tools to interact with the digital product model, which can be useful in various phases of the product development process. They can support an early and intensive information exchange between marketing, design, process planning and manufacturing experts, allowing an easy concurrent involvement of heterogeneous competencies and interacting with a single virtual product model. However, the fruitful adoption of VR technologies implies the rethinking of way of execution of traditional design activities in order to structure new processes. But many companies lack tools and data to estimate the achievable concrete benefits, considering also the counterpart of high investments necessary for VR systems implementation. The effective evaluation of VR systems in the CE context, in terms of product quality improvement, of time to market and cost reduction is the aim of our research. The present work proposes a methodology to measure the VR performances using a metrics-based approach. First experimental results related to the method application are reported analyzing the conceptual design process and the design reviews tasks for the styling product development.

Keywords. Virtual Reality, metrics, time compression technologies

Introduction

Manufacturing companies are developing their products by capturing the Product Requirements (PRs) from the customer along with the strategies of the company, and turning theses requirements into realizable product and manufacturing system solutions. In addition to the PRs, the company needs to consider business requirements, which are mirroring quality and productivity demands of the customer on the manufacturing system. In order to deliver the product according to all the demands, company needs to coordinate the development of the product and its manufacturing system. One way to structure the development process is to use a supporting method that allows capturing and representing the design intent, the design history and the design decisions made by the developers in a single and shared product model. Obviously, the product and manufacturing system models are developed in an organization consisting of niche professionals, distributed throughout different organizational entities. In order to improve productivity, quality and reduce costs, products and manufacturing processes have to be simultaneously designed and managed (Concurrent Engineering). Digital technologies allowing an advanced interaction with the virtual mock-ups in the early

[1] Corresponding Author: Maura Mengoni, Polytechnic University of Marche, Via Brecce Bianche, Department of Mechanics, 60100 Italy, m.mengoni@univpm.it

phases of the product development process can be a useful support for the CE implementation. In our study we analyze the usability of Virtual Reality (VR) and Virtual Environments (VE) tools. In this context the adoption of VR systems, designed and customized on the need of the specific company, can be accepted if it is possible quantify the achievable benefits in terms of time, quality and cost, but also if these benefits can be estimated in relation to the concurrent processes (design/planning/manufacturing). Our research focuses on how these benefits can be objectively measured. A benchmarking program and related metrics to explore advantages and disadvantages connected with the new design technology have been studied. Currently, the research effort has been dedicated to the design process, focusing on the analysis of styling products development. The main goals of the benchmarking are both to measure the performance of the VE-based concurrent design processes by meaningful test cases and to define the VR tools possible improvements to optimize the concurrent engineering process.

1. Research context

In industry, VRs have proven to be an effective tool for helping workers evaluates product designs. In 1998, BMW explored the capability of virtual reality for verifying assembly and maintenance processes [1]. They tested the VR potentialities to reduce the number of physical mock-ups, to improve overall product quality, and to obtain quick answers in an intuitive way during the conceptual phase of a product. This successful example of VR application in the industrial field shows that it can effectively represent a solution to several product design needs. Another recent example of the use of VR systems for industrial design applications is reported in Weiss [2]: he describes how a passive stereoscopy projection system can support the design process of a refrigerator. He presents a solution dedicated exclusively to product visualisation and neglects how can be supported the process iterations due to design review activities. Application of virtual reality technology provides not only a tool for product analysis, it also offers opportunities for intended users to synthesise design information themselves. A scenario-based product design process supported by VR systems for industrial design applications is described in [3]. It can be an approach to embody the VR systems within a structured design process. However, as reported in [4], there is no one single approach to VR application, but rather a set of related strategies and models that are mainly used at the later stages of the design process. Instead we believe that most advantages can be achieved using them along all the design workflow, especially along the first phases. Experienced practitioners in the field of VR have indicated that to work effectively in a Virtual Environment (VE), the application content must include the ability to access or change environmental/system/meta parameters, create and manipulate particular objects, perform analyses, and export changes to permanent storage. While the current state of VE development has advanced its techniques to support these tasks, rarely does one find complete VEs that achieve both a high-quality photorealistic real-time environment and the level of interactivity required to carry out sufficiently complex real-world tasks, a meaningful case is the *Design Review* (DR) process during styling products development.

From a technological point of view, there are various VR implementations and these can be classified broadly into three categories: desktop systems, semi-immersive and fully immersive systems depending on the sophistication of the technologies being

used [5], [6]. Each category can be ranked by the sense of immersion or degree of presence it provides. Presence is generally believed to be the product of several parameters including level of interactivity, image complexity, stereoscopic view and the update rate of the display. Most of these systems have been implemented within research laboratories. However, there is a poor penetration in the industrial world. An important motivation can be recognised in the difficulty of an objective evaluation of benefits generated using a specific VR technology within a particular product development phase. In literature lacks a rigorous methodology to evaluate the performances of the VR systems use within an industrial design process. Our idea is to define metrics to measure the performance of the design process deployed by VR systems. A preliminary metrics list and a way to realise the related benchmarking program have been described in the present work.

2. Design process analysis and formalization

Design is an activity that is rarely undertaken and completed by any one individual. From a design perspective, complex design problems generally require more knowledge than any one single person possesses because the knowledge relevant to a problem is usually distributed among stakeholders. As the engineering world adopts methods such as concurrent engineering, designers are being required to collaborate with customers, marketing people, manufacturing engineers, suppliers, distributors, end-of-life personnel, and all other stakeholders that are likely to be affected by the evolving design process. One immediate benefit of this type of collaborative work is the coming together of participants with heterogeneous skills, who, on sharing their knowledge, skills, expertise and insight, create what is known as distributed cognition. The collaboration of individuals with different insights, tacit knowledge and expertise generally results in the generation of new insights, new ideas and new artifacts. Therefore, cooperative multidisciplinary design teams dispersed across the enterprise have to be supported and, the management of distributed information and knowledge has to be facilitated within what is known as a distributed design environment. VEs can be a valid tool to support the collaborative process around the product virtual model.

An industrial design process can be seen as executing a series of design goals to arrive an acceptable solution. The design tasks are often defined by the industry's needs in the early design phases. The goals the product must to achieve are related to style, manufacturing technology and budget. Based on objectives a set of important design constraints and product requirements are listed in the *product brief* given to the designers. Designers sketch to explore design solutions and communicate with others. Thanks to the wide development of CAS/CAID tools nowadays designers usually interpret and transform the 2D geometries into a 3D product model in order to represent the complex aesthetic shapes.

Analysing the typical product workflow (figure 1), we synthesize three critical phases in the design process:

The first step, called 1° check point, when the company's decision making group analyses different design solutions and chooses which one better answers to their requirements expressed in the *product brief*. The presentation of a digitally modelled object usually comprises not only the 3D model itself, but also photorealistic images rendered from the model and several sketches. The design models are abstract, conceptual and lacking in technological and manufacturing information.

The second phase is characterized by iterative *Design Reviews* (DRs) on the physical prototype in order to define the product form coherently with functions, ergonomics and technological components. This phase can be considered the first collaborative moment between specialists with different abilities whose viewpoints generally conflict. It's generally time consuming. The full-scale physical mock-up, realized by sculpturing clay or milling wood or chalk, is continuously modified according to the suggestions of the technical committee.

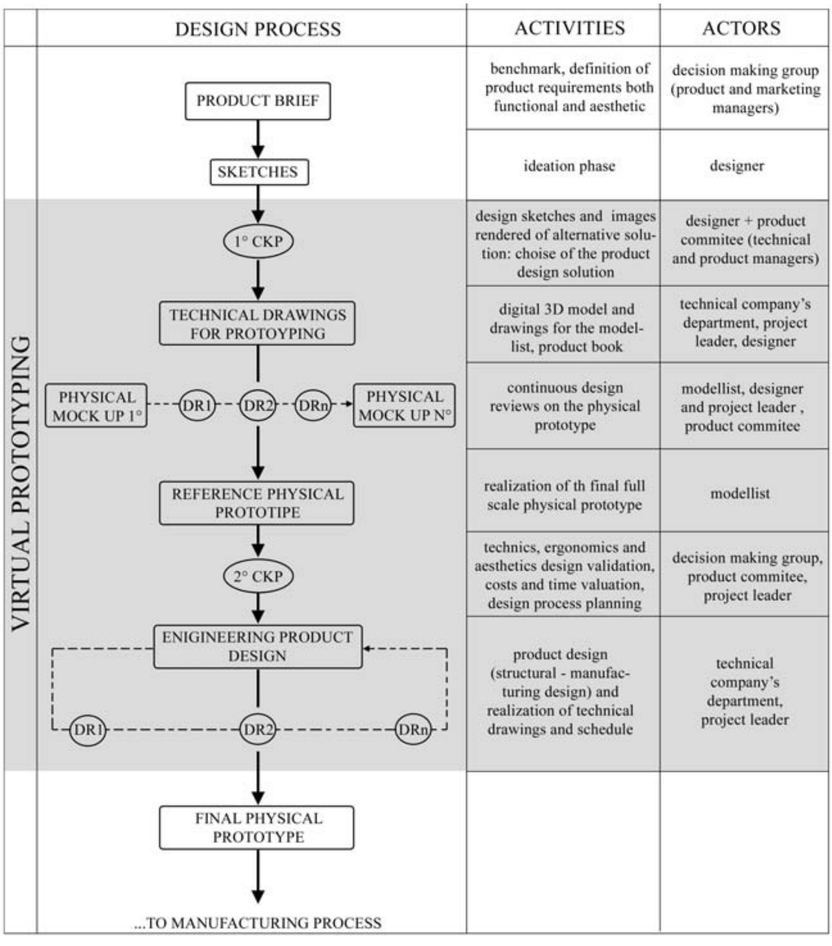

Figure 1. Industrial design process using VR system

The third phase consists in a set of engineering design reviews that take place within the company's technical department. The aim of the design activities is to engineer the product form. The physical prototype is replaced by the CAD model that can be subjected to all kinds of geometrical and functional simulations.

As the design review process needs of physical prototypes, time to market stretches and there can be the loss of the product quality due to the difficulty to assure the correspondence between the design intent and the preliminary brief requirements to the manufactured product model. Virtual Prototyping (VP) is quickly becoming an interesting tool for product development: it allows integrating different viewpoints in

the product common space, to manage product complexity, to increase the number of product variants without realizing several physical mock-ups and finally to reduce product development time and costs.

3. Methodology

In industry, benchmarking is an accepted technique used to identify the strengths and weaknesses of a wide range of processes, procedures, and operations associated with the company business. Benchmarking [7] typically searches for the best practices, thus leading to superior performance. Metrics are quantitative estimates of product and process performances and they can be a tool for developing the benchmarking program. In order to quantify design process improvements by means of VP technology over successive benchmarks, performance measures are essential. A list of metrics have to be established to evaluate what are essentially subjective attributes such as usability, users satisfaction of the new technology, tools integration, non-recurring cost and process/product improvements. We distinguish between *product* metrics, which measure product properties, and *process* metrics, which measure the advantages, related to the use of the VP tools during the whole design workflow.

Table 1. Metrics for VR systems evaluation

Metrics			**Typical Units**
Process	Design Cycle	Process step time	hours
		Number of design phases	number
		Digital components reuse	percentage
		Hardware reuse	percentage
		Software reuse	percentage
		documentation	person-hours
		Software specification	number
	Design Review Process	Users satisfaction	words
		System hardware usability	
		System software usability	
		Physical prototypes	number
	Product Development Process	Workflow activities	number
		Time to repair	minutes
Product	Product quality	Correspondence to brief requirements	number
		Manufacturing iterations	number
		Dependability	number
	Product cost	Manufacturing	person-hours
		Testing	person-hours
		Maintenance	person-hours

The *process* metrics can be classified into three categories: design cycle (from the 1° CKP to the engineering design reviews activities), design review process (that is a sub-class of the first but we have highlighted for its basic relevance to the process analysis), product development process that comprises all the activities that can be further accomplished by the VE (design planning, marketing, trade fair organization designing, decision making group meetings, teleconference moments…)

Each metric is related to a certain unit, specified as part of its definition. We explain in more detail the less intuitive.

- *number of design phases* = it allows to measure the reduction of the cycle design time;
- *digital components reuse* = it quantifies the degree of VP ideation's potentialities in the definition of customized products. It can be measured by the percentage of the components, materials or additional functions presence in different models of the same line of products;
- *hardware and software reuse* = it measures the degree of VP integration in all the phases of design cycle;
- *software specification* = it is quantified by the number of files used in the VE and the files' formats measure the degree of software tool integration;
- *users satisfaction, easy to use, hardware and software usability* = they assess the VP impact in the design review sessions.
- *physical prototypes* = it evaluates if the full scale virtual prototype is enough detailed to assess the product;
- *workflow activities* = it is the number of the workflow activities that take place in the VP room; it measures the degree of VE flexibility for different product development objectives;
- *manufacturing iterations* = it allows to know the efficiency of DMU simulations to predict the real behaviour of a product.

Once defined the metrics and the related units it's necessary to compute each of them by analyzing the whole workflow activities deployed by the VE. We have identified two different analysis protocols to quantify the values of design metrics: the first is based on the Diary Study [8], and the second is based on the Video Interaction Analysis (VIA) described by Jordan and Henderson [9].

There have been continuing difficulties with getting access to study engineers and designers at work. The diary study is adopted to elicit information about design cycle activities in terms of both qualitative and quantitative data or a mixture (date, time, documents format, VP users…). The diary is available as an electronic paper based form as a MS word form. In order not to be intrusive by interviewing the VP system's users, the diary study provides a format that can be immediately filled in real time by the researchers observing the activities or by the users themselves. Unlike Culley's [10] diary study's approach based on questionnaires to report design activities, our proposal is focused on a structured data collection where only a simple list of information is required instead of free text. (table 2).

Table 2. Design Cycle information elicited in the information need component of the diary

number	**date**	**VP users**	**Type of activity**	**Product models**	**Format files**	**File names**	**time**
free text	free text	free text	free text	free text	checkbox	checkbox	free text

The aim of the diary is not only to share parameters values but also to structure documents for the following working sessions.

Among the methods that can be applied to evaluate users interaction and experiences in the VEs, VIA is chosen; a video camera positioned in the virtual room

can capture the dynamics of the work sessions and the complexity of interactions, although from a single viewpoint, can record the human activities such as talks, nonverbal interactions, the use of artifacts and technologies and the immediate workplace context available for repeated viewing and analysis. Therefore we can assess the real usability, easy to use and users satisfaction of the new technology. This kind of analysis allows the researchers not only to measure process metrics, in terms of technology usability and of collaboration, but also to define the technology features that could be improved according to the users behaviors. In VIA research technique a team of researchers view segments of tapes selected by the primary investigator and identify design practices, problems related to the immersive technology and resources for their solution. The tables are compiled to check design activities with and without VP system in order to evaluate the real advantages of the new technology by using the metrics measurement.

4. Experimental results

For Teuco Guzzini S.p.a., the industrial partner of this research work, the Department of Mechanics in collaboration with the technical company's department developed a semi-immersive Virtual Prototyping system for the evaluation of the aesthetic aspects, the ergonomic aspects and the functionalities of new industrial design products.

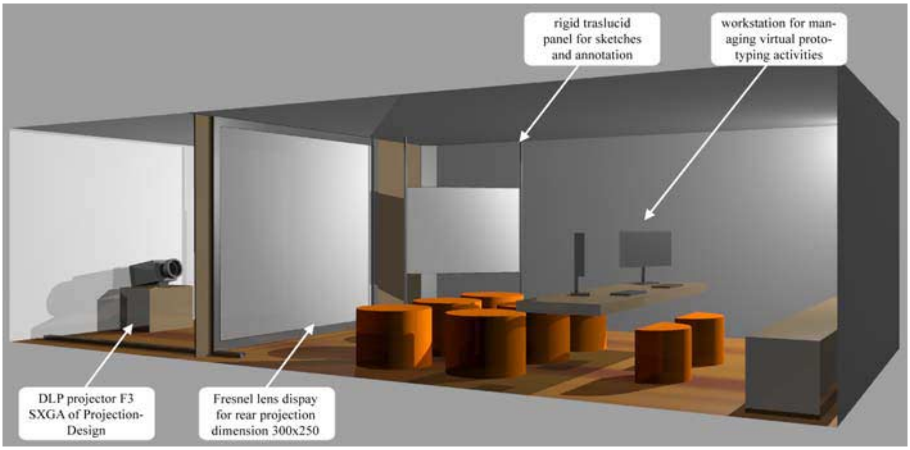

Figure 2. Virtual Reality system implemented

The VE consists of a DLP projector with high luminescence and a rear projection on a diffuser plate (3x2,5 m) made of special Fresnel lens that intensify the main light source. The special form of prisms allows the display to be much more efficient at collecting and directing the light rays in order to improve the image projected quality.

During the present research program experimental phase, University researchers continuously are monitoring the design activities that take place in the virtual room by applying the Diary Study method and the VIA technique.

The industrial design product models displayed in the virtual environments are showers, whirlpool bathtubs, equipped columns, steam saunas and multifunction and fitness corners. All the products are the result of a set of aesthetical and technological features such as wood facings, glass panels, the plastic shells of shower columns and

bathtubs typically in the colors of white and blue and the line of taps and additional functions. Although they belong to products for giving deep sensations of well-being and bodily experiences, they are different in size, shape, materials, manufacturing processes, technological components and additional functions as aromatherapy, chromo therapy and ultrasound massage.

The Virtual Prototyping Room has been built to supply the product's visualization and simulation during the DRs.

As we are developing the benchmarking program on the whole design workflow, our work is mainly focused on the study of the design review activity with the support of virtual prototyping tools. The study was undertaken during two months of design activity on three different wellness products design.

During the design review activities (both aesthetic and engineering) the full scale prototypes were showed as photorealistic images rendered from the models of the prototypes themselves and positioned within different product scenes to evaluate the ergonomic and aesthetic impact, animations of components' mechanic movements in order to analyze the correspondence to the functional and technological requirements, as images of structural and manufacturing analysis of the DMUs. Besides images captured from the models, the virtual room is used to display predefined products presentations, technical schedule and design process planning. During the course of the designing a researcher records all the activities by diary study and VIA technique in order to estimate *product and process* metrics. The Diary Study was structured as a table to be filled during the different working sessions in the virtual room (an example is reported in table 3).

Table 3. Diary study of 3 working session in VP room

work session	date	VP room users	Type of activity	Product	Format files	File names	time
1	03/10/05	technical company's department, project leader	engineering DR	sport spa	.prt, .asm, .doc, .jpg	comp_asm.prt, sportspaver5.asm, images3.jpg, proj_plan.doc	3 h
2	06/10/05	designer, product committee	1° CKP meeting	asym shower	.jpg, .avi, .igs, .pdf, .xls, .doc	scen1_asym.avi, scen2_asym.avi, col_comp.pdf, mat_comp.pdf, asym2.jpg, asym3.jpg, sol1_taps.jpg, sol2_taps.jpg, briefasym.doc	2 h 30 m

The tables are then separately analyzed for each product in order to compile the metrics format.

Table 4 shows an example of the diary study's elaboration for measuring the design cycle metrics (process step time, number of design phases) the DR process metrics (physical prototypes) and the product development process metrics (workflow activities). The VIA technique results are not yet available because the experimental activity is still in progress, and it requires an amount of tapes to give a detailed response.

By analysis technique it was noted that in both the traditional and virtual environment settings a number of similar activities, and interactions styles were common to both approaches: presenting, querying, discussion, revolving, referring to

model or sketch directly by physically touch the screen, analysing the model proportions, changing the viewpoint. Instead of design review activity on the physical prototype the users can evaluate different product solution by simply replacing different taps, colour and materials on the same 3D model, by sketching on the images rendered from the model to understand size, by comparing different product alternatives developed in previous working sessions.

Table 4. Example of diary study elaboration

product name	working session	time	number	physical prototype
ASYM SHOWER	1° check point	3 h 30 min	1	0
	design review	2 h	5	0
		1 h		
		1 h 30 min		
		1 h		
		2 h		
	2° check point	1 h	2	0
		30 min		
	engineering design review	1 h	7	1
		2 h 30 min		
		3 h 30 min		
		1 h		
		3 h		
		2 h		
		1 h		
TOTAL		21 h	15	1

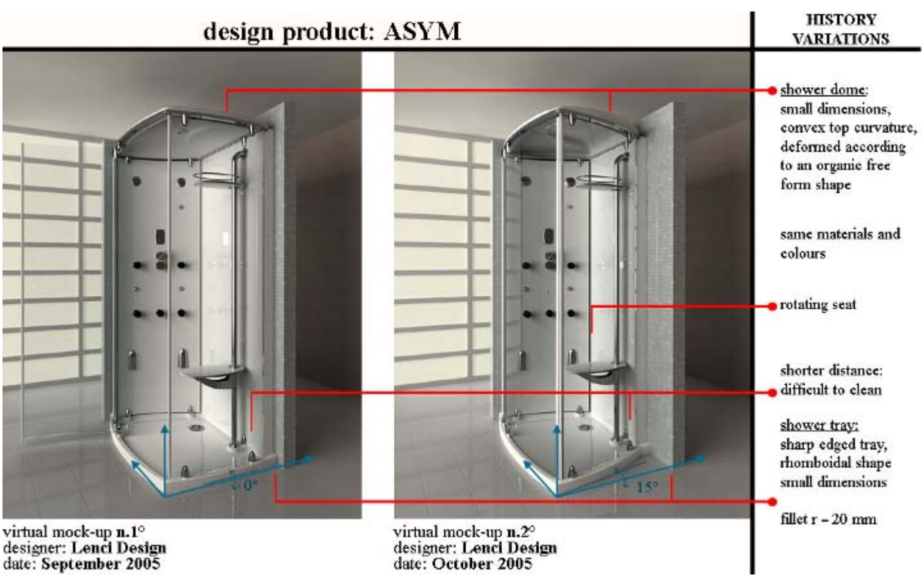

Figure 3. The Asym history comparison

A detailed analysis of the interaction reveals that the semi immersive system is not intrusive: the users are more concentrated on the projected images and animations than on the technology itself, they can discuss about form and function without changing

their viewpoint, they can recall previous product models and compare them (figure 3) The system can be evaluated as a good support to develop a collaboration between different actors, but more extended analysis are needed to validate the results. On the other hand the proposed methodology accomplishes a robust evaluation of system performance in terms of realization of concurrent processes, even if only the conceptual design process has been considered.

5. Conclusions

Being highly innovative, virtual reality environments require dedicated decision making processes to be evaluated in terms of cost/benefits and applicability in a CE context. Therefore, the need for appropriate benchmarking methodologies is imperative. The proposed *process and product* metrics form a sound basis to objectively measure the advantages connected with the implementation of the virtual technology in the design workflow. It is proposed to use both diary study protocol and VIA technique for metrics measuring. The role of the semi-immersive system is to minimise the effect of the misunderstandings that might be generated by the (otherwise beneficial) functional and semantic distribution during DR activities, the time spent for searching and retrieval of information (datasheet, technical schedule, components models, virtual prototyping history…) for design planning and for the comparison of the product design history, the effort of information translation between different tools and the administration and organisational efforts not directly related to the design process (e.g. revision control).

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Enterprise system implementation in integrated context

P.M. Wognum
University of Twente, Faculty of Business, Public Administration and Technology, Department of Operations, Organisation and Human Resources Management, P.O. Box 217, 7500 AE Enschede, The Netherlands
E-mail: p.m.wognum@utwente.nl, Phone: +31 534893736, Fax: +31 534892159

Abstract
Integration within and between companies is facilitated and supported by means of enterprise systems like Enterprise Resource Planning (ERP) and Product Data Management/Product Lifecycle Management (PDM/PLM) systems. Despite the many successes that have been reported in the literature, in many companies the promise of enterprise systems is often not or only partly achieved. Implementation of such systems appears to be extremely difficult and complex.
An enterprise system implementation project is multifaceted and different for each context. Business processes often need to be aligned with the best practices embedded in the enterprise system, while taking into account many other factors. In this paper, a model is offered to support start-up and execution of enterprise system implementation projects. It supports taking into account context-specific factors that make one project different from another. The model is based on results from the IST project BEST (Better Enterprise SysTem implementation). Based on the model a prototype tool has been developed to support improvement of enterprise system implementation projects by identifying weak areas and facilitating learning from previous experience.

Introduction

Globalisation, increased focus on the customer, and new technologies have enabled new ways of doing business, characterized by increased collaboration between companies in supply chains and networks [1]. Such collaboration can only be effective and efficient if information flows seamlessly within and between companies and when business processes are integrated. Enterprise systems, like Enterprise Resource Planning (ERP) and Product Data Management/Product Lifecycle Management (PDM/PLM) support integration within and between companies [2][3]. By means of a central database all parties involved in the relevant business processes can easily access and exchange information. Enterprise systems are mostly offered as integrated packages, which are based on best practices in various industrial and service areas (see e.g., www.sap.com).

The envisioned success of enterprise systems is, however, often not achieved [4] [5]. Implementation of enterprise systems appears to be extremely difficult [6][7]. Enterprise system implementation projects are multifaceted, dynamic and complex. Despite the many general project and change management methods, problems seem to reoccur. It seems to be difficult to translate such methods to the situation at hand. At

the same time projects are highly context-sensitive, making them different in each new situation. Besides the technical problem to align organization and enterprise system many other factors need to be taken into account [8][9].

In this paper a systematic way is offered to consider factors important for enterprise system implementation. A model is presented that integrates several co-existing views. The model can be used to analyse projects at start-up and during execution to improve sub-optimal situations. Based on results of European-wide studies of past enterprise system implementation projects the model has been specialized and implemented into an assessment tool. The tool can be used to identify weak spots in an actual implementation project. Through the tool users can learn from previous experience and define improvement actions for their project situation.

After a brief description of the background of the research in section2, the model will be presented in section 3, while the tool will be introduced in section 3. The paper ends with a summary and ideas for further research.

Background

For many decades, problems have been reported with implementing new technology in organizations (see e.g., [9][10]). A large part of these problems appears to be human and organizational in nature with only a limited part of a technical nature [8]. Many dos and don'ts have been formulated [2][5][9][12] to prevent those problems as well as generic project and change management methods. However, because problems seem to reoccur [2][6][12] specifying these approaches in specific situations seems difficult.

Enterprise system implementation projects are inherently complex and dynamic. Implementation of an enterprise system in an organisation has a large impact. Not only the technical infrastructure needs to be adapted, but also business processes, jobs, authorities and responsibilities, information standards and ways of working need to be changed. An enterprise system also influences a business strategy and profitability, as well as relationships with suppliers and customers. In addition, the enterprise system needs to be tuned to the business. As such, an enterprise system and the organisation co-develop [3][9]. Consequently, an enterprise system implementation project requires collaboration between many different disciplines and organisational levels [12]. Such a project is difficult to oversee from the start because of its size and complexity. Many adaptations and changes to the project are needed as more knowledge is gained.

Because each company is different and business processes and people involved are different, each enterprise system implementation project is different. In the literature, problems have often been abstracted from their real context. Learning about such problems is useful, but recognizing their relevance in a particular situation is not straightforward. The same applies to generic project and change management methods. It seems necessary to support people in analyzing and judging a particular enterprise system implementation situation.

In the IST project BEST (Better Enterprise SysTem implementation - www.best-project.com) Europe-wide case studies have been performed in companies that have implemented an enterprise system in the near past. The goal of the project has been to improve enterprise system implementation project start-up by facilitating learning from past experience. The research has adopted a socio-technical approach, in which organizations and information technology are considered to co-develop and need to be aligned [3].

In the BEST project a model has been used that has been developed specifically as a reference for enterprise system implementation. The model incorporates the several different aspects and dimensions that have appeared to play a role in enterprise system implementation. The model has served to structure the knowledge gathered in the case studies and for building the prototype tool.

Model of enterprise system implementation

The model of enterprise system implementation as used in the BEST project is based on a process-based systems view of organizations [1][13]. An organization is considered as a purposeful whole, which satisfies particular goals in its environment. To satisfy these goals the system transforms particular inputs into outputs in terms of products and services that are desired by the environment. To achieve the goals of an organization processes are performed by means of people with help of means, like machines, tools, knowledge and skills. Primary processes are directly aimed at producing the products and services, while management processes buffer the primary processes against environmental disturbances and support processes provide the primary processes with sufficient and sufficiently qualified people and means. Strategic management processes set the long-term goals and strategy of an organization, adaptive management implements the chosen strategy, and operational management guards the daily execution of the business processes. Organisational arrangements are the formal and informal, structural and cultural rules, procedures, tasks, responsibilities and authorities, which are the glue between the process activities and the people and means. A subset of the model (see below) is depicted in figure 1.

The process-based system model of organizations can be applied to any process, like an R&D process [14], collaborative R&D between two R&D centres [15], or a manufacturing process [10]. Determining the borders of the system to be studied depends on the scope of the focus process. An order throughput process, for example, involves many organizational departments and often parts of suppliers and customer organizations. The same accounts for a product development process taking into account upstream and downstream activities, like in Concurrent Engineering. In using the process-based system model in a socio-technical approach, the behaviour of the system should also be taken into account. In observing human action differences from intended system behaviour may be identified. Different behaviour, in turn, may lead to changes in organizational system configuration. In the model developed for the BEST project behaviour is denoted as social dynamics.

In an enterprise system implementation project three organisational systems co-exist. First of all, the daily business must continue during enterprise system implementation. Second, the implementation project can be considered as a separate organisational system, albeit temporary. Third, the enterprise system to be implemented brings its own process and process structure. These three organisational systems co-exist and should be aligned. The three co-existing systems are called dimensions in the BEST model.

After a thorough investigation into experiences of enterprise system implementation consultants, the process-based organisational system model has been adapted to reflect the most important problem areas as discovered in the gathered experiences. The resulting model is depicted in figure 1 and explained below. The elements of the model are called aspects. The model has been applied to each of the

dimensions introduced above, which leads to specific views on the aspects in each of the dimensions. In an enterprise system implementation project, the degree of alignment between dimensions on each of the aspects is essential. We will come back to this point in describing the tool in the next section.

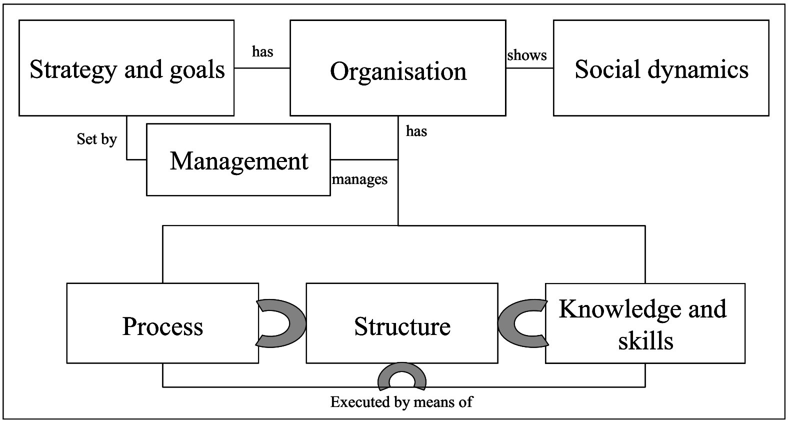

Figure 1 Process-based model of an organisational system in the context of enterprise system implementation

The aspects and relationships of the model can be described as follows:

- Strategy and goals.
  - Business. An organisation has goals and a strategy for achieving them. The goals and strategy should be explicit. An enterprise system implementation project and an enterprise system should contribute to these goals and strategy [2].
  - Implementation project. The goals and strategy of an implementation project should support achieving the business goals.
  - Enterprise system. The goals and strategy of an enterprise system are embedded in its best practices. Understanding these best practices is essential for understanding the alignment with the business goals.
- Management
  - Business. Strategic management in the business sets the goals and strategy, while adaptive management implements the strategy and operational management manages the daily processes. All relevant management roles and management levels should be involved in decisions with respect to the enterprise system to be implemented and should support the implementation project [6].
  - Implementation project. The management of the implementation project is concerned with managing the project and with aligning the project and the enterprise system with the business.
  - Enterprise system. Management in the enterprise system is embedded in the best practices.
- Process
  - Business. The business processes that need to be considered are those that are affected by the implementation of an enterprise system. The business process often has to be changed to achieve optimal results from implementing an enterprise system.

  - Implementation project. The focus process of the implementation project consists of all activities that are needed to execute the project.
  - Enterprise system. Best-practice activities are the elements of the enterprise system process. Most vendors of enterprise system packages offer process maps that can be compared with the business process activities. Tuning the best practices to the business process is an essential part of enterprise system implementation.
- Structure.
  - Business. Structure in the business consists of the activity structure, business hierarchy, rules and procedures, which relate people, means and process activities, and team structures. In the BEST model, people and means are replaced by knowledge and skills, because these have appeared to be the essential characteristics to be considered for enterprise system implementation.
  - Implementation project. Structure in an enterprise system implementation project reflects team structures, but also the order in which project activities are performed and the assignment of tasks to people and the use of project management methods.
  - Enterprise system. Structure in an enterprise system denotes the structure of process activities, system architecture, and relationships between activities and roles expected for executing these, in other words the embedded rules and procedures.
- Knowledge and skills
  - Business. In the business the knowledge and skills available for implementing and using the enterprise system need to be considered. In this way the alignment of the business with the project and the enterprise system can be analysed.
  - Implementation project. The implementation project poses demands and constraints on the necessary knowledge and skills. These demands and constraints should be matched with the available knowledge and skills.
  - Enterprise system. Similarly, the enterprise system poses demands on the knowledge and skills needed for its use.
- Social-dynamics
  - Business. Social dynamics in the business consists of the current culture, attitude, and commitment towards implementing and using the enterprise system. Social dynamics should be analysed on all levels in the organisation.
  - Implementation project. Social dynamics in the implementation project consists of team spirit, communication within team and with the business, and openness.
  - Enterprise system. For the enterprise system dimension, this aspect may consist of the degree of adaptability of the enterprise system and willingness of the vendor to adapt the system.

The dimensions and aspects together form a matrix, which is depicted in figure 2. The resulting model is a model of enterprise system implementation as used in the Best project for structuring the knowledge gathered in the case studies. The case studies are briefly described in the next section.

	Enterprise system	Project management	Permanent business
Strategy and goals			
Management			
Structure			
Process			
Knowledge and skills			
Social dynamics			

Figure 2 Model of enterprise system implementation

An assessment tool

The model above has been further specified for enterprise system implementation projects by means of in-depth retrospective case studies. In the case studies knowledge has been gathered on the process of enterprise system implementation. The construct used to gather knowledge is the CEAO (cause-event-action-outcome) chain. Each chain can be considered as a process fragment that exemplifies cause and consequence of an event that needed attention.

In each case study, several roles have been interviewed, like a project manager, an end-user, an IT person, and a senior manager. Each person has been asked to remember three or more events that required attention and action. After prioritizing these events, for the three top-most events, causes, as perceived by each interviewee, have been listed. After that, the actions taken to deal with the event as well as the outcomes of each of the actions have been listed.

In total 264 CEAO chains have been gathered in 24 case studies all over Europe. For each case a demographic questionnaire has been filled out to gather knowledge on the context in which the enterprise system has been implemented, like the size of the company, the cultural region, the type of enterprise system, the type of company, the number of end-users, etc. Through the demographic questionnaire the context for each of the chains is available. By performing analysis on the CEAO chains, differences between contexts can be explored. Also differences between roles participating in the project can be identified.

The model of enterprise system implementation presented above has been used to structure the CEAO chains, in particular, the cause part of the chains (see for more extensive results [16]). Each of the six aspects for each of the three dimensions has been refined with specific knowledge of real practice thus creating a reference model for enterprise system implementation. The reference model has been used to specify questions and answers for each aspect within each dimension. Each question has several answers, which are rated on a scale from 0 to 4, where 0 means no alignment between dimensions and 4 means optimal alignment. In this way, a maturity assessment in terms of degree of alignment between dimensions can be made of a

specific situation. The questions and answers have been implemented into a prototype tool for assessing an enterprise system implementation project and detect sub-optimal situations that need improvement. The tool is useful for any phase of the project, but especially at the start-up phase to prevent unnecessary problems at an early stage. A result of a session with the tool is presented in figure 3. Social dynamics, strategy and goals and knowledge and skills have been identified as weak in the situation at hand.

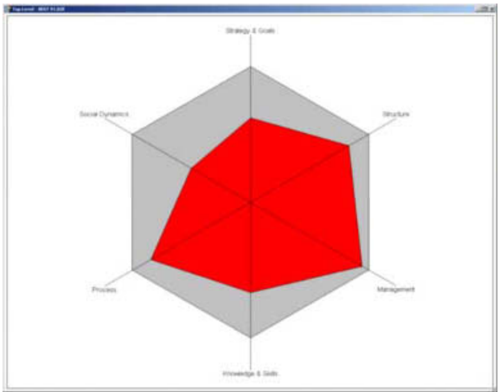

Figure 3 Output of a session with the prototype assessment tool

After an assessment session, the tool can present the CEAO chains that apply to the specific situation. The CEAO chains act as mini-cases, which can help people to learn from past experiences and interpret these experiences for their own situation. The tool is considered useful for people that have expertise of enterprise system implementation, like consultants or business analysts, for translating the results to the relevant people in the organisation.

By means of statistical analysis of the chains and the context from the demographic questionnaire, differences between contexts have been identified [16]. The results form an interesting starting point for further research into these differences. Knowledge of differences between contexts and people roles may help to understand the relevance of previous knowledge and experiences and support the use of general methods.

Summary

In this paper, an approach has been presented for improving the start-up and execution of an enterprise system implementation project. Such a project is performed in complex situations, which require integration of processes not only within the organisation, but also with relevant parties in its environment. The approach identifies several co-existing organisational system that need to be considered together and need to be aligned. For each system the relevant aspects have been identified that have appeared to play a role in enterprise system implementation.

The approach has resulted in a prototype assessment tool to improve the start-up and execution of enterprise system implementation projects. The prototype tool has proven to be useful by means of an extensive validation with enterprise system implementation experts. Further research is necessary to improve the tool and better understand the context-sensitive nature of enterprise system implementation.

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A Value Creation Planning Method to Complex Engineering Products Development

Marcus Vinicius Pereira PESSÔA[a, 1], Geilson LOUREIRO [b] and João Murta ALVES [c]
[a] *Departamento de Controle do Espaço Aéreo – DECEA, Brazil*
[b] *Instituto de Pesquisas Espaciais – INPE, Brazil*
[c] *Instituto Tecnológico de Aeronáutica – ITA, Brazil*

Abstract: Innovative firms have product development as one of their core processes; optimizing this process, regardless the product will be mass-produced or custom made, must be a firm's priority. A common approach is to treat the product development as a project, where Project Management is essential to organize and lead the efforts. The Toyota development system is a benchmark in the automotive industry and has been widely accepted in other sectors with dramatic benefits. This work presents an approach to derive a project activity network pulled by the stakeholders' requested value. The first part of the paper introduces the value creation in product development. In sequence the issues to planning to lean development are discussed. Finally the four-step approach is presented and the first three steps are explained through the analysis of real project data.

Keywords: Lean development, project planning, value creation

Introduction

New product development (PD) can be understood as some kind of information based factory [1]. The goal of the PD process is to create a "recipe" for producing a product [2], which reduces risk and uncertainty at the same time with the target to gradually develop a new and error-free product which can then be realized by manufacturing, sold, and delivered to the customer.

PD is a problem-solving and knowledge-accumulation process. Progress is made and value is added by creating useful information that reduces uncertainty and/or ambiguity [3], [4], [5]. But it is challenging to produce information at the right time, when it will be most useful [6], [7]. Developing complex and/or novel systems multiplies these challenges; the coupling of individual components or modules may turn engineering changes in a component into "snowballs", in some cases causing long rework cycles and turning virtually impossible to anticipate the final outcome [8].

Not surprisingly, overtime, over budget and low quality are commonplaces on PD projects. A great exception on this scenario, and benchmark on the automotive industry, is the Toyota Motor Company. Toyota has, consistently, succeeded on its PD projects, presenting productivity four times better then their rivals [9]. To deliver better products

[1] Corresponding Author E-mail: mvppessoa@gmail.com.

faster and cheaper, some firms are attempting to use the same principles as Toyota's, and create "lean PD" processes that continuously add customer value (i.e., that sustain a level of "progress" toward their goals) [10], [11]. Unfortunately, unlike Toyota Production System (TPS), that was formalized by Shigeo Shingo and enforced by Taichii Ohno, the Toyota development system has not been well documented [12], [13].

All of these issues point to the need for a formal way to turn operational the Toyota's lean practices on PD. This paper proposes an approach to derive a project activity network that is based on a value creation sequenced set of confirmation events that pulls only the necessary and sufficient information and materials from the product development team. The paper shows how both accomplish the two elements of creating value [6]: (1) maximizing the value creation by doing the right job and (2) minimizing the waste in the process by doing the job right.

The goal of this paper is to advance the theory and practice of planning projects of PD. The paper contributes a method that helps (1) managers to add value by focusing effort on eliminating the critical sources of risk in their projects and (2) planners to ensure that a proposed process addresses all of the known significant sources of performance risk

After discussing the concepts and methods used to formulate the planning method, the paper shows how to apply the approach using an industrial example, an aircraft stall recovery device.

1. Value creation in product development

In the 1950s, Eiji Toyoda, Shigeo Shingo and Taiichi Ohno at Toyota Motor Company, in Japan, developed the Toyota Production System (TPS). The TPS, which most people now associate with the term Lean or more with the Just-in-time (JIT) principle, was born when Japanese car industry stuck in a severe crisis. At that time it became clear that the only way to escape from the possible impending doom of this industry were drastic changes in efficiency and productivity [14]. This change happened through lean thinking (or philosophy), which is a way to specify value, align the value-added actions, when requested execute these actions without interruption and improve continuously [15]. The lean philosophy was presented to the rest of the world by the results of MIT International Motor Vehicle Program – IMVP [16], whose goal was to compare the performance differences between car companies operating with traditional mass manufacturing systems and those using the TPS.

Meanwhile, these principles have been adopted by diverse sectors of industry such as aerospace, consumer products, metal processing and industrial products [17]. The lean thinking success, though, is not limited to manufacturing. It can be applied to other processes with high cost reduction and quality improvement potential, which is the case of product development [9].

The ideal PD process should work analogously the single-piece flow in manufacturing [15], representing a value flow from conception to production, without stops due to bureaucracy and loop backs to correct errors. On PD, adding customer value can be less a function of doing the right activities (or of not doing the wrong ones) than of getting the right information in the right place at the right time [9], [10]. Hence, the focus of lean must not be restricted to activity "liposuction" (waste reduction), but address the PD process as a system (value creation) [10]. Value creation

can be divided into three phases: value identification, value proposition and value delivery [6].

The value, as defined by the final client, is the basis of lean thinking. On a program or project, the value is the *reason d'être* of the project team, which means they must understand all the required product/service characteristics regarding the value that all stakeholders on the program expect to receive during the product life cycle [9], [6], [18].

There is no recipe, though, to value creation. Value is: (1) personal, because something of high importance to a group or person may not be valuable to others; (2) temporal, since it is not static, but evolve according to stakeholders' change of priorities; (3) systemic and enterprise wide, as the parts, subsystems or company's sectors only add value if they contribute for the whole; and (4) fuzzy at the beginning of the lifecycle, due to the few information available to determine the whole value and, sometimes, even the final client [6].

The value proposition (project plan) implements the strategy to efficiently deliver the value to all stakeholders. It formalizes the program objectives, defines the stakeholders' relationships and determines schedule and budget. At this moment explicit or implicit trade-offs are made, in order to: (1) include all stakeholders; (2) solve conflicts; (3) include all tangible and intangible values (or anything that might have been forgotten) [6]. Therefore, the program's activity network must represent the value stream, where all the tasks in a program are directed to creating deliverables, which are themselves pulled by the value stated by the stakeholders [18].

Unperceived or unsolved problems during value identification are the more expensive to solve, causing more waste and rework; and no efficient use of lean practices and tools during value delivery (project execution) can overcame poor decision during the value proposition creation (product design and project planning).

Toyota applies a set of tools and techniques that help on solving these issues [19]. The approach presented in this paper is aligned to some of them, which affect directly the program activity network definition, they are: trade-off curves, Set-based Concurrent Engineering – SBCE and pull events.

1.1. Trade-off curves

A trade-off curve is an important tool to solve conflicts among system requirements during the Toyota development process [19]. Besides helping on decision making, it is a simple and practical way to reuse knowledge [9].

1.2. Set-Based Concurrent Engineering – SBCE

SBCE is an upgrade of the concept of concurrent engineering used by Toyota. SBCE allows decisions to be delayed and design options to remain open until it is absolutely necessary to select a point solution [11]. SBCE is a set of simple and repetitive development cycles that achieve high innovation in products and manufacturing systems, avoiding risk through redundancy, robustness and knowledge capture [9].

During SBCE, the development team does not establish an early system level design, but instead establishes sets of possibilities for each subsystem, many of which are carried far into the design process (Figure 1). These sets consider all functional and manufacturing perspectives, building redundancy to risk while maintaining design flexibility. The final system design is developed through systematic combining and

narrowing of these sets, when alternatives are eliminated according to the growth of knowledge and confidence [9]. The achieved knowledge is then captured in the trade-off curves.

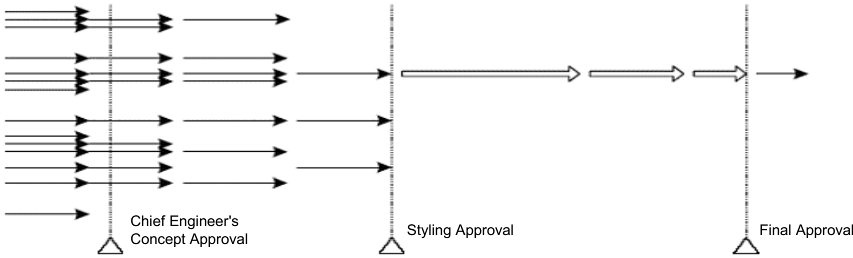

Figure 1: Set-Based Concurrent Engineering.

1.3. Pull events

No process along the value flow should produce an item, part, service or information without direct request from the following processes [15]. By pushing work results to the next processes the enterprise creates an inventory no one wants. On a project the final client must pull the value from the project team [18].

On the Toyota development system, the pull events arte associated to physical progress evidences (i.e., models, prototypes, start of production, etc.) and are important moments to knowledge capture. Differently from tall gates where information batches are created, pull events guarantee the value flow, make quality problems visible and create knowledge. On this context, the planning activity is decentralized, the chief-engineer has a macro schedule containing the pull events dates and each team has their own plans to guarantee the pull event realization and success [19].

2. Planning to value creation issues

It is well known that progress in PD is difficult to predict in a project management plan. Risk and rework provides a great complication. PD planners often "plan to succeed," typically paying little attention to process failure modes and their effects (i.e., rework) [10]. Since PD is a nonlinear process [20], [21], it is harder to determine what value is added and when. Especially in novel PD, design elements are proposed, analyzed, evaluated, and advanced or rejected. The effect of one activity changing its approach and outputs can "snowball" throughout the process, changing other activities' inputs and assumptions and causing rework. PD processes typically have lots of change and rework [8]. The values of its activities are not predetermined—they are partly a function of the information they use and create, and therefore of the activities that precede them and those that follow [10].

The use of the "original" pull system concept on PD, then, is not possible: there is no totally predetermined way of developing the product, since downstream functions cannot really pull the information from upstream functions as they do not know the final output of the work they are supposed to do, not to mention the final product with all its specifications. However, there is also some predetermination of and in developing processes since the overall process follow certain logical orders and is not performed in an arbitrary manner. Experience from the last projects and especially

from other simultaneously ongoing development projects gives a good idea of required input information and output results [1].

The widespread approach to define the strategy to PD is trough project management (PM). Traditional PM planning is based on a Work Breakdown Structure – WBS, that aims to reduce complexity and increase manageability and control by decomposing work [22], [23]. This approach embodies a transformation view, where production is conceptualized as a transformation of inputs to outputs. Furthermore, the management-as-planning perspective assumes a strong causal connection between the actions of management and outcomes of the organization. By assuming that translating a plan into action is the simple process of issuing "orders", it takes plan production to be essentially synonymous with action. [24] These issues have the same effect as MRP on manufacturing, not being able to deal with changes during execution and creating a huge amount of waste on the development system [25].

Thus, one cannot equate added customer value with progress through an arbitrarily defined schedule for several reasons: it may contain superfluous activities for which no value is added, and it may not account for missing activities, rework, or iterations. This is a significant weakness of the Gantt charts and PERT/CPM network diagrams currently used in industry [26]. No schedule can make effective fine-grained work assignments in a complex environment with even modest variability [25].

Even agile alternatives, such as SCRUM [27] and Last Planner [28], [29], do not fit lean development. They basically decrease the size and increase de amount of iterations, but not embody an alternate to the transformation view, such as flow or value aggregation.

3. Value Creation Planning Method - VCPM

The approach described in this section applies the lean principles, based on value creation and waste reduction, to derive a project activity network that is based on a value creation sequenced set of confirmation events that pulls only the necessary and sufficient information and materials from the product development team.

The purposed method has four steps where: (1) value as stated by the stakeholders is determined, understood and structured; (2) an organization that allows value delivery is defined; (3) the events that will implement the value flow are listed; and (4) the project activities are pulled from the project development teams.

3.1. Value Breakdown Structure determination

A program does not provide value unless it has all the capacity requested by the stakeholders. These capacities must be translated into identifiable functions and measurable parameters that can be designed, produced and verified.

The Value Breakdown Structure – VBS represents the project value tree, where the value as stated by all the stakeholders is: (1) understood and deployed into a set of unequivocal value items; and (2) translated into measures of effectiveness (ME). Those measures, unless clearly requested by one stakeholder, will be defined as acceptable ranges (that will be narrowed during SBCE) instead of point values.

The VBS differs from the usual WBS, where the latter decompose the work, to make major project deliverables or perform project phases, into smaller and more manageable chunks, and the former deploys the stakeholders' value into unequivocal

and verifiable parameters, called value items (Figure 2). While the WBS gives support to the transformation view [24], the VBS is the basis of the value aggregation view.

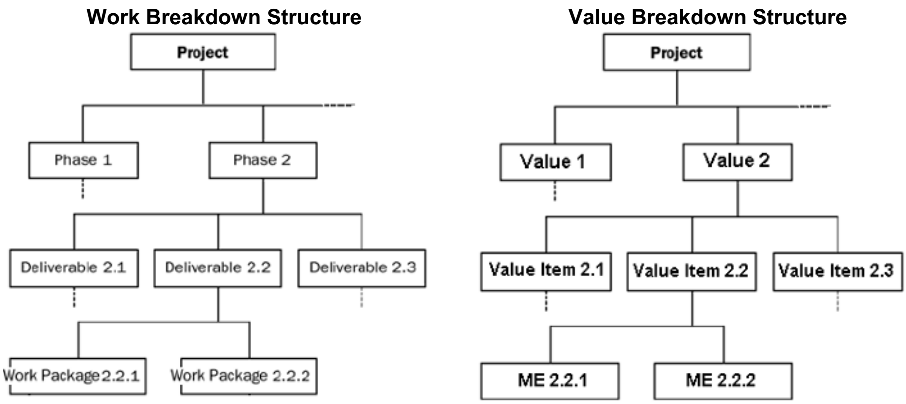

Figure 2: VBS and WBS structures comparison.

3.2. System value delivery organization determination

On product architecture, the functions to be performed are assigned to physical elements and the interactions among them are defined [30]. On the value delivery architecture (1) the value items are assigned to each product-organization subsystem that will deliver it to the stakeholders; and (3) it is determined whether a particular subsystem will be developed through a set of alternatives, instead of relying on the point based approach.

A product-organization subsystem is any group in the company, whose duty is to deliver some value subset. These groups are organized around product modules or enterprise functions (i.e., production, logistics, etc.).

Once the use of parallel development on all subsystem may not be necessary, useful or possible a strategy must be defined. This approach proposes that the subsystems which deliver more value and/or have higher risks on delivering this very value (the higher f (value, risk)) are the best candidates to perform parallel development.

3.3. Pull events definition

Pull events have three roles: (1) they guarantee that project activities will be pulled and not pushed; (2) they allow combining and narrowing alternatives in SBCE; and (3) they constitute learning moments. On the purposed approach, the successful end of confirmation task (i.e., reviews, tests, etc.), which reduce the uncertainty and risk on PD, were chosen as pull events. The iterations among value items and the resulting value creation sequencing are the main drivers of pull events. Identified value items conflicts are addressed, in order to exploit potential opportunities.

The related value items and corresponding product-organization subsystems define each event scope. The final pull events set must guarantee the right level of confirmation to each value item, according to its importance, criticality and probability

of failure. Each event scope must be designed against failures and not just to fit the specification [31]. Imperfect reviews and tests are causes of loop backs and rework.

3.4. Activities pulling

The purpose of the project activities should be progressively decrease performance uncertainty and risk. The activities are pulled from each value delivery architecture component by the related pull events. Each component must provide all and only the required information, parts, prototypes, etc. to enable each confirmation event. During execution, the confirmation events signal the related subsystems to start their work, avoiding the waste created by early definition/creation of unnecessary information/parts. Thus, a pulled flow of information is created, instead of the pushed flow that is a characteristic from traditional schedules [24].

4. The Tailchute project example

As the basis for a contrived example of development planning, we use data collected from a finished and successful project, which produced a stall recovery system (Figure 3) to be used during flight tests.

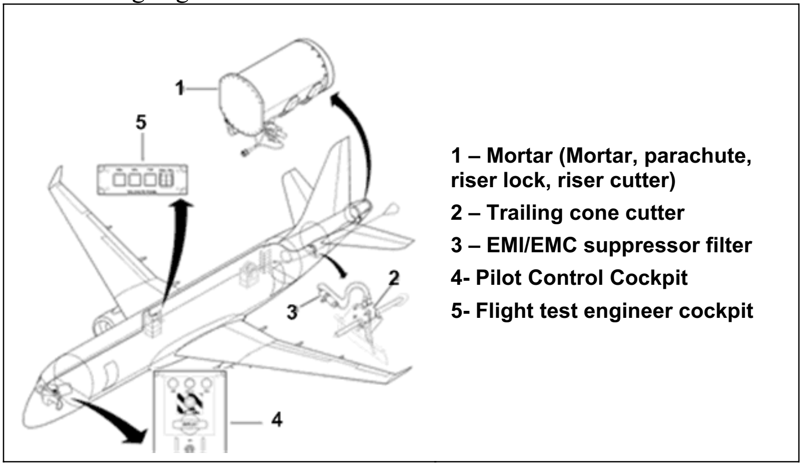

Figure 3 – Tailchute System.

This section presents the Tailchute data and discusses some insights from the value-to-confirmation table. Then, a hypothetical project planning is presented and discussed.

4.1. Actual data analysis

Figure 4 shows the set of value items identified from the project contract and specifications and the value confirmation tasks presented on the homologation plan and project schedule. On this value-to-confirmation table, the items were correlated according to the type of review: A - Analysis, I – Inspection, C - Calculus, D - Demonstration and T - Test. The need for verification of each value item (***f*** (importance, severity, probability)) and the total amount of verifications is also shown.

Some insights from the table were: (1) value items, such as “parachute riser length” and “cross section”, were not really values, but point solutions early defined; (2) Some items, such as “parachute deployment” and “load transfer”, received less attention than its importance; (3) other items, such as “pilot (panel)” and “flight engineer (panel)”, were over tested; (4) the correlation between importance and amount of verification was very low (r2 = 0.29).

Some adjustments on this same table, trying to correct some of the perceived discrepancies, led to an r2 = 0.66. All of these suggest that the activity network that supported these events was far from the ideal value creation.

Requirements from Contract and Product Specifications	Planned reviews and tests from homologation plan												Verification Needs	Actual Verifications
	SDR	PDR	EMF1	EMF2	EMF3	EMF4	PT	FHFT	ET	CDR	GT	FQR		
Parachute Deployment	A	A				D	T		D	A	T	A	144,0	81
Deployment Velocity	A					D			T	A		A	47,0	50
Drag Load	A	C					T			A		A	50,9	35
Parachute Riser Lenght	A						T			A	T	A	96,0	65
Parachute Jettisoning	A	A						D		A	T	A	24,9	51
Load Transfer	A	C			D	D			T	A	T	A	117,6	105
Cross Section	A		D						T	A	T	A	16,6	90
Mechanical	A	C						D		A	T	A	12,0	60
Electrical	A	C			D			D		A	T	A	22,0	65
Mass	A	A					I			A		A	5,4	9
Tailing cone cutter	A	A		D					T	A	T	A	47,0	91
Pilot	A	A						D		A	T	A	1,8	51
Flight test engineer	A	A						D		A	T	A	1,8	51
Stand-by Mode	A	A						D		A	T	A	4,7	51
Armed mode	A	A			D			D		A	T	A	14,1	56
Fail Mode	A	A						D		A		A	32,0	11
Parachute opening interference avoidance	A	A		D					T	A	T	A	144,0	91
Unintended parachute deployment avoidance	A	A						D		A		A	144,0	11
Parachute Latching	A	A			D				T	A	T	A	144,0	91
Test mode	A	A						D		A	T	A	18,8	51
Back-up power operation	A	A						D		A		A	28,2	11
Mechanical fail proof	A	C	D	D	D				T	C		A	144,0	88
MTBF of electonical circuitry > 1000 h	A									A		A	9,4	5
Redundant pirothecnics	A		D	D					T	A		A	50,9	55
Technical manuals	A									A		A	2,7	5
Pirothecnics test equipment	A											A	33,9	3
Fast post deploy repair	A										D	A	0,6	13
Tranpostability of repair kit	A										D	A	0,3	13
Usefull life	A									A		A	24,0	5
Techinical support	A											A	14,7	3
Temperature	A		D	D		D			T	A		A	96,0	60
Humidity	A								T	A		A	33,9	45
Vibration	A								T	A		A	96,0	45
Storage	A											A	0,2	3
	System Design Review	Preliminary Design Review	Functional Model	Functional Model	Functional Model	Functional Model	Parachute Test	Integration Test	Environmental Tests	Critical Design Review	Ground Test	Formal Qualification		

Figure 4- Value-to-Confirmation Table.

4.2. Hypothetical project planning

A new problem analysis was made and a value tree was created from the set of four root values: (1) realign the aircraft; (2) provide safe and reliable operation; (3) operate installed on a determined aircraft family; and (4) allow quick and easy maintenance. Though the value items dependencies a Design Structure Matrix – DSM was used to create the value items sequence with smaller loop backs (Figure 5).

		5	11	12	13	16	17	18	20	21	23	24	25	31	19	28	4	14	2	3	6	15	7	10	8	9	1	22	29	26	27	32	30
1.2.2 Time to realign the aircraft > Ts	5	5																															
2.2.1 Usefull life	11		11																														
2.2.2 Mechanical fail proof	12			12																													
2.2.3 MTBF of electonical circuitry > 10C	13				13																												
2.3.2 Electrical guarantee	16					16																											
3.1.1 Mass > X	17						17																										
3.2.1 Dimensions and connections	18							18																									
3.2.3 Interference areas	20								20																								
3.3.1 Voltage, Amperage and Conectors	21									21																							
3.5.1 Temperature	23										23																						
3.5.2 Humidity	24											24																					
3.5.3 Vibtarion	25												25																				
3.4.2 Logical concept	31													31																			
3.2.2 Load transfer	19							1							19																		
4.3 Suportar Z anos de estocagem	28		1													28																	
1.2.1 Drag Load	4	1					1		1						1		4																
2.3.1 Logical guarantee (stand-by mode)	14		1		1	1		1		1	1	1	1	1				14															
1.1.2 Clear parachute envelope	2	1	1	1	1	1		1	1	1	1	1	1	1					2			1								1			
1.1.3 Deployment sequence > Ts	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1				1	3		1								1			
1.3.1 No aero dynamical effect	6			1	1	1				1	1	1	1	1						1	6	1								1			
2.3.2 Phisical guarantee	15			1							1	1	1		1		1			1	1	15											
1.3.2 No electrical effect	7				1	1				1	1	1	1	1									7							1			
2.1.3 Ground test Equipment	10																		1	1	1			10						1	1		
2.1.1 Auto-test mode	8				1	1				1	1	1	1	1				1							8		1						
2.1.2 Fail mode	9							1						1											1	9							
1.1.1 Armed mode	1				1	1		1		1				1				1								1	1					1	
3.4.1 Operational procedure	22													1				1		1	1		1		1	1	1	22	1			1	
4.4 Possuir manuais técnicos	29							1	1	1	1	1	1	1		1	1	1	1	1	1		1	1	1	1	1	1	29	1	1	1	
4.1 Post deploy repair < X	26																												1	26			
4.2 Tempo manutenção corretiva < Y	27																												1		27		
2.3.3 Lock	32			1							1	1	1	1			1			1		1								1		32	
4.5 Maintanence procedure	30																												1	1	1		30

Figure 5 – Parameter based DSM of the value items.

The DSM method uses a "n-squared" matrix to depict the information flows from one task to another, the relationship among design parameters or the communication across the project teams. The matrix can be numerically optimized to minimize iterations and maximize the potential for concurrent work. A good description of the method can be found in [32].

The lower left quadrant of the DSM helped on the determination of pulling events. On this quadrant are excluded the dependencies among, to and from the external input parameters of the project (items 5, 11, 12, 13, 16, 17, 18, 20, 21, 23, 24 and 25). The activities were pulled by the resulting future state value-to-confirmation table.

4.3. Lessons learned and results

During the case study the greatest challenge was the value items set definition and the determination of the iterations among them. A poor work on this step leads to an incorrect project scope and/or an inconsistent value creation sequence.

According to the development team, some positive results achieved were: (1) a better test and homologation plan; (2) the clear verification event scope definition; and (3) a sequence of activities that really described the work sequence and that allowed the cooperation among the subsystems teams.

5. Conclusion and future work

The research method presented in this paper provides a useful approach to planning to complex engineering products development. The method can be summarized in four steps where: (1) value as stated by the stakeholders is determined, understood and structured; (2) an architecture that allows value delivery is defined; (3) the events that will implement the value flow are listed; and (4) the project activities are pulled from

the project development teams. An application to the development an aerospace project demonstrated that the method improves value identification and proposition.

This work contributes to the PD discipline by the appliance of the lean principles, based on value creation and waste reduction, to derive a project activity network that is based on a value creation sequenced set of confirmation events that pulls only the necessary and sufficient information and materials from the product development team.

Future work includes the analysis of the pulled events effectiveness during the program execution and their effect on control.

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Author Index

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